StarTran Automated Vehicle Location System

SYSTEM ARCHITECTURE ANALYSIS

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1 INTRODUCTION

1.1 Scope of This Project

The City of Lincoln, Nebraska's StarTran, as a fixed route and demand-responsive transit provider, wishes to improve the operational efficiency and security of its transit system. These desires can be summarized in three main goals:

- Increased availability of transit information and dissemination;
- Improved overall dispatching and operating efficiency; and
- Increased driver and passenger safety and security.

StarTran is tasked with providing these improvements while minimizing additional expenditures or personnel. The existing system, because of the inherently manual nature of its data sharing, precludes the ability to increase system efficiency without the application of additional resources.

Like many other transit system operators, StarTran has identified Automated Vehicle Location (AVL) technology deployment as a method to accomplish these goals. Specifically, the appropriate implementation of Intelligent Transportation System (ITS) technology to improve data accuracy and reduce communication delays offers the potential to meet these three main goals without additional personnel resources, and with minimal, if any, increase in recurring operational costs. Further, the City of Lincoln desires that any StarTran AVL system provide future expandability and interoperability capabilities for other City of Lincoln (or even State of Nebraska) fleets, as well as neighboring transit providers. Given this desire, a stand-alone system is unlikely to satisfy the system requirements. Therefore, StarTran, along with the City of Lincoln and a grant from the Federal Transit Administration (FTA), has undertaken the process to design an open AVL system.

1.2 Purpose

This document applies to the StarTran AVL system. The document control number for this document is contained in the document footer, and the file name for the electronic rendition of the document is recorded in the table of contents for the document. A System Architecture Analysis provides a conceptual framework, or frame of reference, for the planning, analysis, and design of a system.

The framework of this System Architecture Analysis is organized into one or more constituents called (architectural) views. Each view addresses one or more of the concerns of the system stakeholders. The term view is used to refer to the expression of a system's architecture with respect to a particular viewpoint.

The proposed system inhabits an environment comprised of the setting and circumstances of developmental, operational, political, and other influences upon that system. The environment can include other systems that interact with the system of interest, either directly via interfaces or indirectly in other ways. The environment determines the boundaries that define the scope of interest of the system relative to other systems.

The StarTran AVL System project has multiple stakeholders. Each stakeholder typically has interests in, or concerns relative to, this system. Concerns are those interests which pertain to the system's development, its operation, or any other aspects that are critical or otherwise important to one or more stakeholders. Concerns include system considerations such as performance, reliability, security, distribution, and growth.

The system exists to fulfill one or more missions in its environment. A mission is a use or operation for which a system is intended by one or more stakeholders to meet some set of objectives.

1.3 Definitions, Acronyms, and Abbreviations

This document may contain terms, acronyms, and abbreviations that are unfamiliar to the reader. A dictionary of these terms, acronyms, and abbreviations can be found in Appendix A.

1.4 References

The following documents contain additional information pertaining to this project or have been referenced within this document.

1. *IEEE Standard 1471-2000, IEEE Recommended Practice for Architectural Description of Software-Intensive Systems*, ISBN 0-7381-2518-0 SH94869, The Institute of Electrical and Electronics Engineers, Inc., 2000.
2. Request for Proposals, Specification No. 05-053, City of Lincoln, NE, March 2005.
3. Consulting Services for Automated Vehicle Location System Proposal, Mixon/Hill, Inc., April 2005.
4. "Application for Participation in the Fiscal Year (FY) 2004 Intelligent Transportation System (ITS) Integration Component of the ITS Deployment Program – AVL System for StarTran," StarTran, January 20, 2005.
5. *National ITS Architecture*, Federal Highway Administration (FHWA), 2003.
6. Title 23 Code of Federal Regulations (CFR) §940 (ITS Final Rule), and as referenced in Title 49 CFR §600 (FTA Regulations).
7. "StarTran Automated Vehicle Location System, Concept of Operations", November 2005, Mixon/Hill, Inc.

1.5 Document Overview

The organization and content of this System Architecture Analysis, and the selection of viewpoints, is based on IEEE standard 1471-2000 and FTA and FHWA requirements as expressed in 23 CFR 940.

The remainder of this document consists of the following sections and content:

> **Section 2 (Stakeholders and Concerns)** identifies the stakeholders and their interests with regard to the system development, operation, policies, and other impacts of the system.

Section 3 (Operational Viewpoint) provides the participating agencies with an overview of the purpose, scope, and roles played by the system. It also addresses policy statements about the system and policies governing the interactions between the system and external systems, agencies, and users.

Section 4 (Information Viewpoint) provides the System developers and other interfacing systems' developers with an overview of the data schemas, data interfaces, and data flows for the system.

Section 5 (Software Viewpoint) provides the System developers and other interfacing systems' developers with an overview of the computational objects (software modules), program interactions and behavior, and software interfaces that form the system.

Section 6 (Hardware Viewpoint) provides the system developers, communication system designers, network system designers, hardware designers, and system maintenance and support staff with an overview of the planning for the hardware, communications, and operational support for the system.

Section 7 (Technology Viewpoint) provides the system developers, communication system designers, network system designers, hardware designers, and system maintenance and support staff with an overview of what relevant technologies will be used, how industry standards and specifications will be implemented, and what technologies will be required to support testing of the system.

Section 8 (National ITS Architecture Viewpoint) provides the Federal Transit Administration, participating agencies, and other interested parties with an understanding of how the proposed system fits into the National ITS Architecture. This includes the system's relationship to the standard market packages and to the National ITS Physical and Logical Architectures.

Section 9 (Regional ITS Architecture Viewpoint) provides the participating agencies, regional architecture maintainers, and other interested parties with an understanding of how the proposed system fits into the Regional ITS Architectures. This includes the system's impact on the regional architectures and the system's relationship to the standard market packages and to the National ITS Physical and Logical Architectures.

Appendix A (Definitions, Acronyms, and Abbreviations) provides definitions for the terms, acronyms, and abbreviations used throughout the document.

2 STAKEHOLDERS AND CONCERNS

This section identifies the stakeholders and concerns considered by the architect in formulating the architectural concept for the system.

The stakeholders considered and consulted during the system development are numerous. In addition, stakeholders not currently aware of the potential capabilities of the ultimate StarTran AVL system were considered during system analysis, as they may become interested stakeholders after the StarTran AVL system is deployed.

The list of stakeholders generally falls into two categories: system managers and system users. As evidenced below, system managers and system users may play duel roles. System managers are those individuals, employed by StarTran or their contractors and partners, who keep the system operational and populated with accurate and timely information. Examples of these individuals include StarTran dispatchers; StarTran bus operators; City of Lincoln information technology (IT), radio, and telecommunications personnel; and Transport Plus bus operators. System users are those individuals that utilize the system to assist with their responsibilities. These users may be general citizens, private companies, or even owner agencies and their contractors and partners. Examples of these users include StarTran riders, StarTran dispatchers, StarTran bus operators, Transport Plus bus operators, StarTran fleet maintenance, law enforcement, fire departments, and first responders. These individuals utilize the system to expedite their travels on the StarTran system and to improve their operational efficiencies and response times to situations involving the StarTran system.

Although stakeholder interests will vary by whether they are managers or users, they do share some common concerns. These include whether or not the system information is accurate, whether necessary information is provided in a timely fashion, and whether the system's data interfaces are easily used.

2.1.1 Organizational Structure

The StarTran organizational structure exists to ensure the public, as the primary system user, has access to a safe, efficient transit system within the City of Lincoln. The Transit Manager serves as the head of StarTran. He reports to the Director of Public Works & Utilities, who reports to the Mayor. The StarTran Advisory Board provides advice on the StarTran system to the Mayor, the Director of Public Works & Utilities, and the City Council. This group is made up of professionals from businesses across the city. Their association with the City of Lincoln is represented by a dotted line. In this proposed organizational structure, additional IT/Telecommunications support is provided for the StarTran AVL system. The following figure graphically represents the StarTran organization and the IT/Telecommunications support is shown as an integral unit, but not one that directly reports to the Transit Manager as shown with the dotted line.

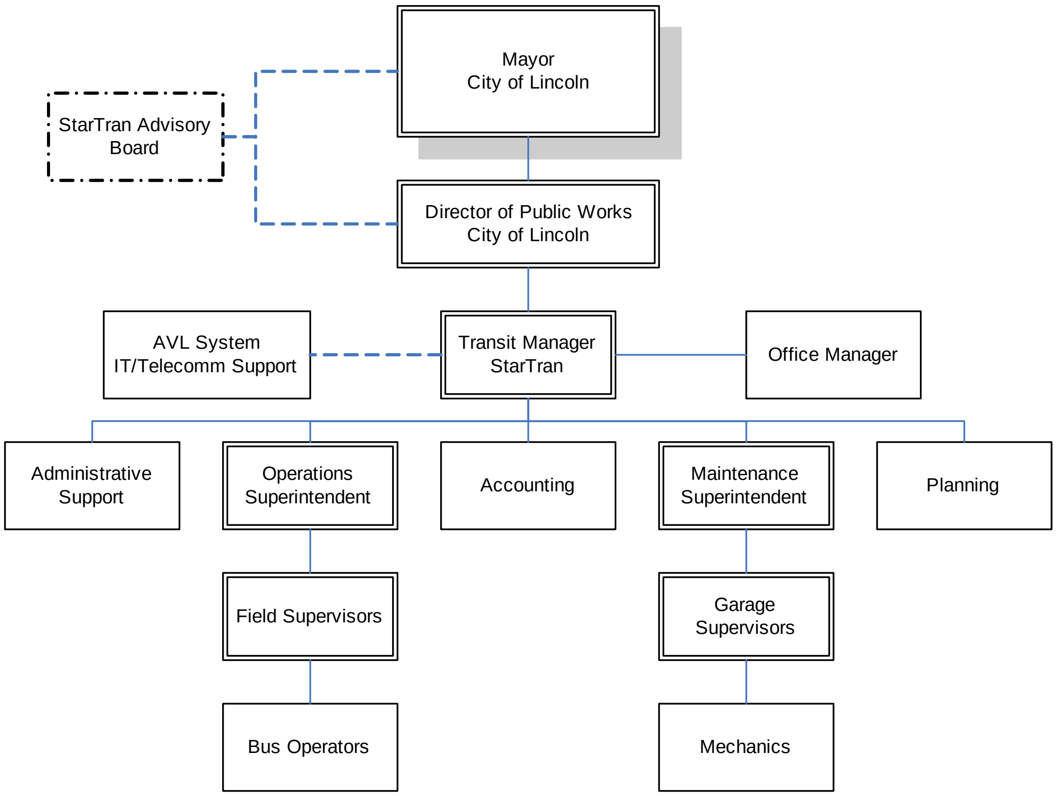

Figure 1 - StarTran Organizational Chart with AVL System

2.1.2 Mission

StarTran is the public transit provider for the City of Lincoln, with an overall mission to provide the citizens of Lincoln a convenient, reliable, comfortable, safe, and affordable public mass transit system. StarTran works to achieve this mission by efficiently serving the public with the highest standards of quality, safety, and responsiveness while working with great commitment to increase the public trust and the community's quality of life.

The mission for the StarTran AVL system is to increase availability of transit information and dissemination, improve overall dispatching and operating efficiency, and increase driver and passenger safety and security. StarTran will accomplish this system mission while minimizing additional expenditures or personnel.

2.1.3 Stakeholder Considerations

The previously identified stakeholders were consulted in determining the system requirements along with organizational needs to satisfy those system requirements. This includes interviews and discussions with the system managers and system users. Their identified concerns were captured and are documented here for consideration by the system designers.

Among the concerns expressed by the system managers, one consistently expressed was the maintenance required to keep the system operational and populated with accurate and timely information. System managers are concerned with the additional financial and personnel commitments any new system will require. The StarTran AVL system design will address these concerns by developing a system that automatically extracts data from the vehicles and aggregates this data into a single management and public distribution data stream. This data will then be automatically available to desktop computer users and mobile users via cellular, wireless web, and other information services. Additional data will be available by request to StarTran administrative personnel, StarTran maintenance personnel, and emergency personnel through a computer interface. While any new system requires some maintenance, the daily operational requirements for the StarTran AVL system will be minimal.

The ability to get useful information in an accurate and timely fashion was among the concerns expressed by the system users. As this is an automated process, the StarTran AVL information will be more accurate and timely than information from existing sources.

The remaining concerns, then, are the feasibility of constructing the system and the risks associated with constructing the system. This system will use proven, commercial off-the-shelf (COTS) components. Therefore, the hardware risk is low. Integration of disparate components from different manufacturers represents a moderate risk, as some data formatting and interface work will likely be required. However, this particular open system model has been used for both commercial and non-commercial applications, so its feasibility has already been demonstrated.

Given the minimal maintenance requirements, user benefits, and feasibility, the stakeholders concerns have either already been addressed or will be incorporated into the system design and construction.

3 OPERATIONAL VIEWPOINT

The Operational Viewpoint provides the participating agencies with an overview of the purpose, scope, and roles played by the system. It also addresses policy statements about the system and policies governing the interactions between the system and external systems, agencies, and users.

3.1 Background, Objectives, and Scope

Operating with a current staff of 112 employees, StarTran served a fixed route ridership of 1,508,073 and a special transportation service ridership of 44,719, for a total 1,719,551 revenue miles during the most recent reporting year. This represented an approximate 3% ridership increase from the previous year. StarTran management anticipates this rate of increase to continue, and wishes to implement systems that can handle not only the projected growth, but can also increase customer satisfaction and safety while minimizing operating expenses.

StarTran, and the City of Lincoln, have identified three goals for their new AVL system. It must:

- Increase availability of transit information and dissemination;
- Improve overall dispatching and operating efficiency; and
- Increase bus operator and bus rider safety and security.

The proposed system must accomplish these goals within the financial constraints of the FY 2004 FTA §5208 Federal-aid, including design and deployment of the initial system. Due to the initial financial constraints, some system capabilities will likely require deployment at a later date.

Therefore, the system must employ an open, standardized design to provide the opportunity for maximum flexibility and minimal expenditures to achieve the system's ultimate functionality. Further, the system might require some not-yet-available capability in the future. This reinforces the need for a standardized and open system design.

3.2 Operational Policies and Constraints

StarTran operates as an autonomous unit of the City of Lincoln Public Works & Utilities Department, and utilizes the information system support services from the City of Lincoln Finance Department. StarTran operates within the bounds established by the City of Lincoln, as well as guidelines provided by FTA. These policies, including Americans with Disabilities Act (ADA) compliance, may impact the design and development of the StarTran AVL system. Further, the capabilities of the information system support services group may impact the final system design.

Capabilities introduced by the StarTran AVL system may also allow for future integration with the City of Lincoln's other departments (i.e. Engineering Services/Street Maintenance, Police, Fire), as well as other public agencies such as Lancaster County Emergency Management and Nebraska Department of Roads (NDOR). While not part of this project, such future integration must be considered during the design process. These considerations may constrain the final system design.

In addition, the proposed system may share infrastructure with the City of Omaha, Metro Area Transit (MAT). Such an arrangement may allow the StarTran AVL system to leverage the existing AVL communication infrastructure at MAT, if possible. Currently, an intergovernmental agreement does not exist between the City of Lincoln/StarTran and the City of Omaha/MAT. As a result, for this functionality to be implemented, an intergovernmental agreement must be implemented between the City of Lincoln/StarTran and the City of Omaha/MAT.

StarTran's defined hours of operation, days of operation, and the number of staff will impact the final system design. The system may provide functionality such as automated scheduling capabilities for demand responsive services. By providing bus riders with the ability to request service via the Internet or other automated methods, this will reduce demands on customer service staff and will provide 24 hour-a-day scheduling capabilities for customers.

In order for the AVL system to offer traffic signal priority capabilities, the City's Engineering Services Unit, specifically the Traffic Operations group, would have to agree with the concept. Then, the work of integrating this capability into the City's existing signal system would fall on the Traffic Operations group.

3.3 Description of the Proposed System

The following section provides a description of the features/functionality for StarTran's AVL system. The essential functions are those defined as critical to the system's success. These functions shall be included in the design and deployment of the initial system.

The remaining capabilities are envisioned in the fully developed, mature AVL system. StarTran will prioritize the development and deployment of these capabilities subsequent to the essential functions. Their inclusion in the initial system deployment will primarily be a function of available funding and existing infrastructure capabilities. Otherwise, they may be scheduled for subsequent deployment phases.

3.3.1 Essential Functions

Essential functions will be specified as requirements in the base system procurement.

3.3.1.1 Precise Vehicle Location Technology

The StarTran AVL system is based on the ability to precisely determine the location of the vehicles within StarTran's fleet. The AVL system includes the ability to automatically transmit location data from the vehicles to the dispatcher. The data may include location, direction of travel, and travel speed. The system shall be able to monitor the entire StarTran fleet, and provide enough capacity for system redundancy with other regional AVL systems.

3.3.1.2 Safety Monitoring Systems

The StarTran AVL system will provide improved bus operator and bus rider safety and security. This feature requires the ability to automatically convey alarms and emergency request information from the bus to the dispatcher; this information will include precise location data. The feature will include an emergency alarm switch to be activated by the vehicle operator and a hidden microphone to allow audio surveillance of the bus when the alarm is triggered. This functionality may eventually be extended to include the ability to transmit real-time images and/or video from the buses to the dispatchers. The exact data qualities (i.e., still or moving images, image quality, frame rate) must be determined during the design process.

3.3.1.3 Open System Design

The StarTran AVL system must be based on an open system design utilizing accepted standards. This feature should allow various hardware components and potential systems from multiple providers to share information. It must allow for future integration with various regional information and management systems. This will reduce the risk of building a stove-piped system that restricts interaction and future expansion. It also ensures future system changes can be accomplished cost effectively.

3.3.2 Desirable Functions

Desirable functions will be specified as options in the base procurement specifications. In the final procurement process, desirable functions will be purchased preferentially over other optional functionality.

3.3.2.1 Vehicle Tracking Capability

The StarTran AVL system shall have the capability of implementing vehicle tracking. This feature would allow dispatchers to observe real-time data regarding a particular bus route and schedule adherence. It would also allow utilization of more sophisticated dispatching systems that could support on-the-go dispatching of Paratransit vehicles. The vehicle tracking capability shall provide a Computer-Aided Dispatch (CAD) system with route and schedule information, and provide customer service staff with the ability to review past route/schedule adherence to assess and address customer questions and concerns.

3.3.2.2 Mobile Data Terminals

The StarTran AVL system shall have the capability of implementing Mobile Data Terminals (MDTs). MDTs will allow two-way communication between the dispatchers and the bus operators, while leaving valuable radio capacity for more urgent communication. These MDTs will provide the ability to convey messages between the dispatcher and the bus operator, and may include the ability to convey information between the bus operator and the fleet maintenance staff. The MDTs may also serve as the mechanism for conveying route/schedule adherence information to the vehicle operators and route/schedule information to an in-bus traveler information system.

3.3.2.3 Traveler Information System

The StarTran AVL system shall have the capability to provide real time schedule and route information to customers. The data may include schedules and actual location, direction of travel, and estimated arrival times at planned bus stops. This information would be disseminated automatically through a variety of methods that may include the Internet, phone, email, text messaging, and/or wireless devices. The system design shall provide for the future addition of traveler information devices not yet identified through standards based interfaces. This system may be a prerequisite for the ADA compliant announcement system.

3.3.2.4 Traveler Planning System

The StarTran AVL system shall have the capability to provide trip-planning services to potential customers. By entering a beginning and ending location, the system will provide the customer with estimated travel times, starting and ending bus stops, transfer locations and times, and estimated fare costs. This system may be provided through the Internet, phone, wireless devices, or other devices not yet identified. Support for such systems would be provided through standards based interfaces.

3.3.2.5 Vehicle Component Monitoring

The StarTran AVL system shall have the capability to monitor various vehicle components. This information would be automatically provided to the bus operator, the dispatcher, and fleet maintenance personnel. The notification system would include alerts when predetermined thresholds are exceeded. The data may include real-time engine, drive train, braking status, and fuel usage rate, as well as advance notification of required preventive maintenance such as oil and transmission fluid changes. This functionality would be based on the existing vehicle automation and information systems on the buses in service and the standard interfaces provided by those systems.

3.3.2.6 System Statistical Reporting

The StarTran AVL system shall have the capability of automatically generating required system statistical reports. These reports are required by the FTA, the City of Lincoln, and others. These reports could include a wide variety of data such as rider counts, revenue miles, peak usage times for specific routes, percent capacity utilization, on time performance, and cost per rider/mile among others. The exact data and reports desired by this functionality shall be determined during the design process.

3.3.3 Optional Functionality

Optional functions represent low priority items which may not be included in the procurement specifications for the base system. In many cases, these functions are dependent on implementation of other “desirable” functions and can only be implemented if those functions are procured and funding allows.

3.3.3.1 Driver Login and Bulk Data Transfer

The StarTran AVL system shall have the capability of allowing the bus operator to login to the AVL system on their assigned bus. A bulk data transfer would load information from the AVL system to the bus internal systems, providing route and schedule information. The AVL systems on the bus should then automatically adjust the head sign and fare structure for the bus operator’s prescribed route. Necessary data will include route and fare data as well as bus operator identification and security authorization. This feature may be a necessary prerequisite for route/schedule adherence information for the vehicle operators and the ADA compliant announcement system.

3.3.3.2 ADA Compliant Announcements

The StarTran AVL system shall have the capability of providing automated, ADA-compliant announcements. This includes advanced notification of upcoming stops, fare changes, and route changes. It may include announcements with real-time schedule data, including estimated travel times and bus transfer information.

3.3.3.3 Automated Fare Payment System

The StarTran AVL system shall have the capability of implementing an automated fare payment system. Such a system may include an automated card for fare payment that is linked to the bus rider's account data. The system will automatically adjust for different routes and different rate schedules. Necessary data will include route identifiers, rate schedules, bus rider automated card identification, and security authorization for account access. This system may be dependent on implementation of the Driver Login and Information Card and MDT systems.

3.3.3.4 Traffic Signal Priority System

The StarTran AVL system shall have the capability of implementing a traffic signal priority system. Such a system will allow the buses to have priority access at a signalized intersection. Data required includes the bus routes and schedules with estimated travel times between stops. It will also include integration with the City's existing signal timing plans, including any alternate plans they may have for events, inclement weather, or emergencies. In most instances, this type of system is implemented through the traffic control systems and is independent of any other systems on the bus.

3.4 Modes of Operation

The operational modes for the proposed system are very basic and display a significant amount of overlap. The modes can be described as normal, peak/degraded, and emergency.

3.4.1 Normal Operational Mode

This is the normal, daily operational mode for the current StarTran system.

3.4.1.1 Customer

The AVL system data regarding both fixed- and demand-responsive route and schedule status is provided to customers through a variety of automated means. When the StarTran staff receives inquiries directly, the staff member obtains the needed information from one of the AVL system's automated methods. The customer can also obtain this information directly via the Internet. Bus information is provided in real-time, is substantially more accurate than currently available data, and includes location, direction, and travel speed.

Potential customers can plan trips utilizing StarTran buses, and receive information regarding starting location and time, ending location and time, any required transfers, and estimated fare cost. Demand-responsive customers can also make automated trip reservations.

3.4.1.2 Fleet Management

Dispatchers, field supervisors, and management have multiple methods of monitoring individual and fleet performance. First, the dispatchers can communicate with the bus operator via two-way radio. This system is constrained by the physical limits of the dispatcher, the bus operator, and the radio communication system. Second, field supervisors can drive throughout the City on recognized routes. By observing routes from a vehicle, they can monitor actual field performance. This method limits the field observations to one-at-a-time observations, limited by their desired mobility from the observation vehicle. Third, field supervisors can ride along a given route. This provides them with in-depth information about the individual bus operator and route/schedule adherence. However, it limits the observation to a single route, unless the field supervisor transfers to another line.

In addition to these three methods, these individuals now can use the AVL system to monitor multiple vehicles, up to the entire active fleet, at one time. This allows the dispatchers and field supervisors to more accurately evaluate bus operator performance, including identifying when buses are on- and off-route, allowing them to correct off-route buses. The AVL system provides off-route or behind schedule alerts to both the dispatcher and the bus operator, helping them to more promptly take corrective action.

Communication between the dispatchers and the bus operators is still conducted over the existing two-way radio system, but at a significantly lower volume. The MDTs are used for routine communication between the dispatcher and the bus operator. In addition, the AVL system has eliminated the need to gather location and schedule information via the two-way radio system.

3.4.1.3 Bus Operator

The bus operator no longer communicates location and schedule information via the two-way radio. The AVL system automatically provides this information to the dispatcher. The MDTs are utilized for virtually all routine communications.

The bus operator logs into the AVL system at the beginning of his or her shift. By identifying the vehicle operator and the assigned route, the head sign is automatically adjusted to reflect the route and the automated, ADA-compliant announcements are loaded into the system as well. The normally reported information such as beginning odometer, ending odometer, and fuel usage are automatically reported by the bus to the AVL system server. That information is made available to the appropriate StarTran personnel.

3.4.1.4 Fleet Maintenance

Fleet maintenance personnel are provided with vehicle monitoring information, including alerts of impending vehicle system failures. The system also provides the fleet maintenance personnel with accurate vehicle information such as beginning odometer, ending odometer, and fuel usage.

This information allows the fleet maintenance personnel to better plan preventive maintenance, and distribute workloads more uniformly over time. It also allows fleet maintenance personnel to more accurately plan for the appropriate bus maintenance part and supply inventories.

3.4.1.5 Emergency Personnel

Under normal operational mode, emergency personnel are not actively involved.

3.4.1.6 Administrative

System administrative functions are largely automated, including the implementation of automated fare payment and reporting systems. The automated fare payment system improves system performance as well as streamlining financial processing costs. The automated reporting systems provide up-to-date system data as needed, and provide the information required for the annual FTA and City of Lincoln system reports.

3.4.2 Peak/Degraded Operational Mode

This is the operational mode experienced during periods of peak usage. In comparison to the current system's peak operational mode, the proposed system does not suffer nearly as much performance degradation. The system operates similarly to the normal operational mode, with a few additions. The proposed system continues to provide customer information with no visible delay over the normal operational mode.

3.4.2.1 Customer

The AVL system data regarding both fixed- and demand-responsive route and schedule status is provided to customers through a variety of automated means. When the StarTran staff receives direct inquiries, the staff member obtains the needed information from one of the AVL system's automated methods. The customer can also obtain this information directly via the Internet. Bus information is provided in real-time, is substantially more accurate than currently available data, and includes location, direction, and travel speed.

Potential customers can plan trips utilizing StarTran buses, and receive information regarding starting location and time, ending location and time, any required transfers, and estimated fare cost. Demand-responsive customers can also make automated trip reservations.

3.4.2.2 Fleet Management

Dispatchers, field supervisors, and management have multiple methods of monitoring individual and fleet performance. First, the dispatchers can communicate with the bus operator via two-way radio. This system is constrained by the physical limits of the dispatcher, the bus operator, and the radio communication system. Second, field supervisors can drive throughout the City on recognized routes. By observing routes from a vehicle, they can monitor actual field performance. This method limits the field observations to one-at-a-time observations, limited by their desired mobility from the observation vehicle. Third, field supervisors can ride along a given route. This provides them with in-depth information about the individual bus operator and route/schedule adherence. However, it limits the observation to a single route, unless the field supervisor transfers to another line.

In addition to these three methods, these individuals now can use the AVL system to monitor multiple vehicles, up to the entire active fleet, at one time. This allows the dispatchers and field supervisors to more accurately evaluate bus operator performance, including identifying when buses are on- and off-route, allowing them to correct off-route buses. The AVL system provides off-route or behind schedule alerts to both the dispatcher and the bus operator, helping them to more promptly take corrective action.

Communication between the dispatchers and the bus operators is still conducted over the existing two-way radio system, but at a significantly lower volume. The MDTs are used for routine communication between the dispatcher and the bus operator. In addition, the AVL system has eliminated the need to gather location and schedule information via the two-way radio system.

Traffic signal priority systems help the StarTran buses remain on schedule, thus ensuring bus riders arrive at their chosen location when expected. Vehicle tracking gains additional visibility as dispatchers and field supervisors verify their vehicle operators are complying with predetermined routes.

3.4.2.3 Bus Operator

The bus operator no longer communicates location and schedule information via the two-way radio. The AVL system automatically provides that information to the dispatcher. The MDTs are utilized for virtually all routine communications.

The bus operator logs into the AVL system at the beginning of his or her shift. By identifying the vehicle operator and the assigned route, the head sign is automatically adjusted to reflect the route and the automated, ADA-compliant announcements are loaded into the system as well. The normally reported information such as beginning odometer, ending odometer, and fuel usage are automatically reported by the bus to the AVL system server. That information is made available to the appropriate StarTran personnel.

3.4.2.4 Fleet Maintenance

Fleet maintenance personnel are provided with vehicle monitoring information, including alerts of impending vehicle system failures. The system also provides the fleet maintenance personnel with accurate vehicle information such as beginning odometer, ending odometer, and fuel usage.

This information allows the fleet maintenance personnel to better plan preventive maintenance, and distribute workloads more uniformly over time. It also allows fleet maintenance personnel to more accurately plan for the appropriate bus maintenance part and supply inventories.

3.4.2.5 Emergency Personnel

Under peak/degraded operational mode, emergency personnel are not actively involved.

3.4.2.6 Administrative

System administrative functions are largely automated, including the implementation of automated fare payment and reporting systems. The automated fare payment system improves system performance as well as streamlining financial processing costs. The automated reporting systems provide up-to-date system data as needed, and provide the information required for the annual FTA and City of Lincoln system reports.

3.4.3 Emergency Operational Mode

This is the operational mode experienced during an emergency event. Such an event may result from a fire or medical emergency in the StarTran dispatch center, an emergency on an active bus, or an initiated homeland security alert. During a dispatch center-based event, communication can be provided through both the two-way radio and through the MDTs. This provides a redundant system for delivering any pertinent message.

During a bus operator-related event, automated communication including location information can expedite police, fire, or emergency management response. Because the system expedites communication of event and location data, risk exposure is lessened for bus operators and passengers.

3.4.3.1 Customer

The AVL system data regarding both fixed- and demand-responsive route and schedule status is provided to customers through a variety of automated means. When the StarTran staff receives direct inquiries, the staff member obtains the needed information from one of the AVL system's automated methods. The customer can also obtain this information directly via the Internet. Bus information is provided in real-time, is substantially more accurate than currently available data, and includes location, direction, and travel speed.

Potential customers can plan trips utilizing StarTran buses, and receive information regarding starting location and time, ending location and time, any required transfers, and estimated fare cost. Demand-responsive customers can also make automated trip reservations.

Further, customer safety is increased due to the dispatcher's ability to remotely monitor not only the bus' location, direction, and speed, but also to remotely view real time camera video/images from inside the bus.

3.4.3.2 Fleet Management

Dispatchers, field supervisors, and management have multiple methods of monitoring individual and fleet performance. First, the dispatchers can communicate with the bus operator via two-way radio. This system is constrained by the physical limits of dispatcher, the bus operator, and the radio communication system. Second, field supervisors can drive throughout the City on recognized routes. By observing routes from a vehicle, they can monitor actual field performance. This method limits the field observations to one-at-a-time observations, limited by their desired mobility from the observation vehicle. Third, field supervisors can ride along a given route. This provides them with in-depth information about the individual bus operator and route/schedule adherence. However, it limits the observation to a single route, unless the field supervisor transfers to another line.

In addition to these three methods, these individuals now can use the AVL system to monitor multiple vehicles, up to the entire active fleet, at one time. This allows the dispatchers and field supervisors to more accurately evaluate bus operator performance, including identifying when buses are on- and off-route, allowing them to correct off-route buses. The AVL system provides off-route or behind schedule alerts to both the dispatcher and the bus operator, helping them to more promptly take corrective action.

For the buses involved in an emergency event, the dispatcher utilizes the AVL information to know where the bus is currently located, where it is headed, and the travel speed. The dispatcher also has access to real-time video/images from inside the bus, and can communicate with the bus operator via the MDT if the two-way radio system is unavailable or undesirable. The dispatcher can relay this information to emergency responders in real-time. For a health/safety emergency, these responders may already know treatment protocol upon arriving at the scene; this can save precious response time. In the case of a hostile takeover, the emergency responders have an assessment of the situation, the location of the offender within the bus, and the possible identification of the offender's weapon, if any.

3.4.3.3 Bus Operator

The bus operator no longer communicates location and schedule information via the two-way radio. The AVL system automatically provides that information to the dispatcher. The MDTs are utilized for virtually all routine communications.

The bus location, direction of travel, and travel speed is provided automatically to the dispatcher, allowing the bus operator to focus on the emergency situation. If the situation involves criminal activity, the bus operator triggers the silent alarm, alerting the dispatcher to the situation. The bus operator then has the capability of discretely communicating situational information via the MDT. The bus operator knows the dispatcher has access to real-time video/images from inside the bus.

3.4.3.4 Fleet Maintenance

Fleet maintenance personnel are provided with vehicle monitoring information, including alerts of impending vehicle system failures. In the event of a bus breakdown, the fleet maintenance personnel know the nature of the breakdown prior to response. Further, the fleet maintenance personnel know the location and direction of travel of the bus. This allows them to assess the possibility of a field repair, and if necessary, arrange for towing and an alternate bus prior to leaving the garage.

In the case of a major repair, the alternate bus and tow vehicles arrive on scene promptly and the disabled bus is removed from the travel way. This reduces the impacts to traffic flow and the bus' schedule. In the case of a minor repair, the fleet maintenance personnel determine the proper traffic control layout en route to the scene. This expedites the field repair and the return of the travel way and the bus' schedule to normal operating conditions.

3.4.3.5 Emergency Personnel

Emergency personnel will be involved in health and safety emergencies, and may be involved during a bus breakdown for traffic control. Emergency personnel learn of the situation from the dispatcher, who has received the information from the bus operator and the AVL system. The emergency personnel have precise location, travel direction, and travel speed information provided either by the AVL system through the dispatcher or directly from the AVL system. This expedites their response to the bus.

Because of the amount of real-time data, the emergency personnel can more directly assess the situation on the bus prior to arrival on scene. The bus operator may continue to provide communication via the MDT, and the dispatcher can relay information from the real-time video/images of the bus' interior. Emergency personnel can determine the location within the bus of the individual with a health emergency, or the location of the offender in the event of a criminal action. They may also be able to determine the offender's type of weapon, if any.

3.4.3.6 Administrative

Under emergency operational mode, administrative personnel are not actively involved.

3.5 User Classes and Other Involved Personnel

This section describes the stakeholders of the proposed StarTran system. It includes not only those groups/individuals that directly interact with the system, but also those groups/individuals that provide support to ensure the system's operational status. Each group/individual will be described below.

3.5.1 Profiles of User Classes

The following subsections describe each of the user classes for the proposed StarTran system. Each description also includes system responsibilities and interactions with the proposed system.

3.5.1.1 StarTran Management and Administrative Staff

StarTran management and administrative staff are characterized as personnel who work primarily in the StarTran office. The staff includes program supervisors, office managers, customer service representatives, and accounts personnel. Their responsibilities include:

- Establishing budgets;
- Providing supervisory oversight;
- Responding to customer requests;
- Aggregating and reporting financial information; and
- Aggregating and reporting ridership information.

These responsibilities are executed with access to real-time data, and reporting functions involve assembling data largely provided by the AVL system. This user class directly interacts with the system, dispatchers/field supervisors, fleet maintenance, bus operators, and customers daily as well as Information technology (IT), radio, telecommunication, and emergency management personnel as needed. This user class also regularly interacts with the management of the various integrated systems, ensuring data integrity and security as well as satisfaction with the results of the system integration.

3.5.1.2 Dispatchers and Field Supervisors

StarTran dispatchers are characterized as personnel who manage the StarTran bus operators. This user class also includes the Operations Superintendent and Field Supervisors. The responsibilities for this user class include:

- Ensuring fixed route service schedule adherence;
- Providing communication between bus operators and customer service representatives;
- Determining location of currently active buses;
- Scheduling demand-responsive or special transportation service requests; and
- Communicating assistance requests from the bus operator to the appropriate emergency personnel.

These responsibilities are executed with direct access to real-time data. Automated data is provided by the system, and additional data is available through either the MDTs or the two-way radio system. Emergency information is also provided by real-time images from the buses. This user class directly interacts with the system, customer service representatives, and bus operators daily, and interacts with IT, radio, telecommunications, and emergency personnel as needed.

3.5.1.3 Fleet Maintenance Personnel

StarTran fleet maintenance personnel are characterized as those individuals that directly maintain fleet equipment. This user class includes the Maintenance Superintendent, the Garage Supervisors, and the mechanic staff. The responsibilities for this user class include:

- Preventative maintenance of StarTran buses;
- Emergency repair of StarTran buses;
- Scheduling preventative fleet maintenance; and
- Maintaining and managing fleet parts inventory.

These responsibilities are executed with access to real-time data, including vehicle component conditions. Preventive maintenance is scheduled with the assistance of real-time mileage/hours data from the system. Unplanned maintenance is performed based upon component condition alerts provided by the system. Field response to broken equipment is expedited by access to the precise location of the vehicle. This user class directly interacts with the system and bus operators daily, and interacts with IT, radio, telecommunications, and emergency personnel as needed.

3.5.1.4 Bus Operators

StarTran bus operators are characterized as those individuals that directly operate the buses and other vehicles that carry bus riders. This includes both StarTran bus operators, paratransit vehicle operators, and Transport Plus bus operators. Their responsibilities include:

- Safely operating the individual buses;

- Providing customer service to bus riders;
- Ensuring route and schedule adherence; and
- Providing bus/equipment repair notification.

These responsibilities are executed with direct access to real-time data. This data is provided by the system and its MDTs, as well as the two-way radio system. Information related to schedule delays is communicated automatically. Fare payments are partially automated. Emergency information may be communicated to dispatchers as alarms or via real-time images from the buses, coupled with real-time location data. This user class directly interacts with the system, dispatchers, and bus riders daily, and interacts with fleet maintenance and emergency personnel as necessary.

3.5.1.5 Bus Riders/Customers

StarTran bus riders are characterized as those individuals that utilize StarTran for public transportation within the City of Lincoln. This includes those individuals who use the fixed service, the demand-responsive service, and the special transportation services such as during University of Nebraska-Lincoln (UNL) sports events. Their responsibilities include:

- Safely using the StarTran service;
- Obtaining appropriate route and schedule information; and
- Providing the appropriate payment for service.

These responsibilities are executed with access to real-time data. Bus riders can obtain real-time route and schedule data, including estimated arrival times for active bus routes. Bus riders can plan their routes using interactive systems that provide starting location and time, ending location and time, and any required transfer information. Bus riders are provided with bus stop, arrival time, and other en route travel information via an automated, ADA-compliant announcement system within each bus. This user class directly interacts with the bus operators daily, and interacts with emergency and customer service personnel as necessary.

3.5.1.6 Police/Fire/Emergency Management Personnel

Emergency personnel are characterized by those individuals who respond to emergency events within the City of Lincoln and Lancaster County. This includes the Lincoln Police Department, Lincoln Fire and Rescue, UNL Police Department, Lancaster County Sheriff, Lincoln-Lancaster County Emergency Management, Nebraska Emergency Management Agency (NEMA), and Nebraska State Patrol (NSP). Their responsibilities include:

- Ensuring public safety;
- Responding to health emergencies, including bus operators and riders;
- Responding to vehicle accidents, including those with StarTran buses; and
- Responding to crime scenes, including those on or involving StarTran buses.

These responsibilities are executed with access to real-time data. Assistance requests are communicated to the StarTran dispatcher via automated systems, MDTs, or the two-way radio system; the StarTran dispatcher then contacts the appropriate emergency personnel via 911 or direct line. Upon contacting the appropriate emergency personnel, the StarTran dispatcher can provide the exact location, direction of travel, and speed of the bus. This user class directly interacts with the dispatchers, bus operators, and bus riders as necessary.

3.5.1.7 IT/Radio/Telecommunications

IT, radio, and telecommunications personnel are the individuals that install, maintain, and operate the various information systems used by StarTran. This user class includes computer personnel, network engineers, radio technicians, and telecommunications specialists. The responsibilities of this user class include:

- Installing new computer networks, and radio and telecommunications systems;
- Maintaining and operating existing computer networks, and radio and telecommunications systems; and
- Supporting the City of Lincoln and Lancaster County agencies in their use of computers and networks, radio systems, and telecommunications systems.

These responsibilities are executed with access to real-time data about the information systems, and generally real-time data about the activities the information systems support. System maintenance scheduling is based on planned preventive system maintenance, as well as reaction to unforeseen system failures. This user class directly interacts with the system, and management and administrative personnel daily. They interact with dispatchers, field supervisors, and fleet maintenance personnel as needed.

3.5.2 Other Involved Personnel

3.5.2.1 Transport Plus

Transport Plus is a private transit company that supports StarTran. Through a contract with StarTran, they provide vehicles to supplement StarTran's HandiVan fleet for large special transportation service events, when the demand for paratransit exceeds StarTran's capability, or in the event an inordinate amount of StarTran's normal fleet is undergoing maintenance. In this capacity, Transport Plus may operate as bus operator and fleet maintenance among others. Therefore, Transport Plus has an interest in any existing or proposed StarTran system.

3.5.2.2 StarTran Advisory Board

The StarTran Advisory Board makes initial review of and acts upon matters related to the operation of the system, including transit related studies and plans, route studies and evaluations, performance indicators, fares, and schedules. They meet monthly with the StarTran staff, and as needed during committee meetings.

3.5.2.3 City of Lincoln/Mayor/City Council

The region's political bodies provide the vast majority of the financial support for the StarTran system. The City of Lincoln provides approximately two-thirds of StarTran's annual operating budget. This budget is authorized by the City's political bodies on behalf of the area's constituents. These bodies have a direct interest in ensuring StarTran operates as efficiently and effectively as possible.

3.5.2.4 Lincoln Metropolitan Planning Organization (MPO)

The Lincoln MPO is the region's overall planning organization. This agency studies the region's growth patterns, specifically how they relate to the transportation system. Based on this information, and coupled with system needs provided by the Department of Public Works & Utilities, the Lincoln MPO prepares a five-year Transportation Improvement Plan (TIP), as well as a 20-year Long Range Transportation Plan (LRTP). The projects listed in these documents are intended to reflect the community values and visions for improving the overall transportation system, including StarTran projects.

3.5.2.5 Omaha MAT

Omaha MAT is the transit provider in the City of Omaha, Nebraska metropolitan area. Because of the close proximity between Lincoln and Omaha, interest naturally exists in the adjacent region's public transportation system. Administrative components of the Omaha MAT could provide redundancy for StarTran (or vice-versa) in the event of a homeland security or other large-scale emergency. Because of these situations, the Omaha MAT has an interest in StarTran's existing system and any potential modifications.

3.5.2.6 Nebraska Emergency Management Agency (NEMA)

NEMA is the statewide agency responsible for coordinating response actions to natural and homeland security emergencies. This agency directs the application of statewide resources to respond to emergencies within the State of Nebraska. Any incident management systems or activities will involve NEMA.

3.5.2.7 Nebraska Department of Roads (NDOR)

NDOR has responsibility for all state highways and roads. As such, NDOR has deployed several systems which could be leveraged with the StarTran AVL system, including road weather information systems (RWIS), commercial vehicle operations (CVO) systems, and freeway management systems (FMS). These systems can provide information that may support the StarTran system operation, and may, in turn, benefit from data provided by the StarTran AVL system.

3.5.3 Interaction Among User Classes

Interaction among each of the user classes has been identified in the particular user class. However, the types of interactions among the user classes will be discussed here.

The routine system operation is generally automated, with interaction occurring between the system and the user classes identified above. The bus operators operate the buses and work to maintain route and schedule adherence. Much of the schedule data is automatically reported from the bus to the dispatcher by the system. Requests for health, safety, or equipment emergencies are provided by the bus operators to their dispatcher via MDTs or two-way radios; the dispatcher then relays the request to emergency management or fleet maintenance personnel respectively along with detailed location and direction data. Routine preventive maintenance is scheduled by fleet maintenance personnel with no interaction required by the bus operator; the system provides the information automatically.

Route or schedule variance is provided to bus riders whenever desired, and is provided in real-time. The information may be provided via Internet, text messaging, email, or other means. Long-term and temporary route or schedule adjustments are provided via the StarTran website.

IT/radio/telecommunications personnel interact with each unit within StarTran. They receive requests for system upgrades and repairs, perform those activities, and provide feedback to the appropriate unit regarding system changes. They support the system's electronic infrastructure, providing the systems that allow the various user classes to communicate. The IT, radio, and telecommunications personnel also support the information systems that gather StarTran financial and statistical information, aggregate the systems for reporting, and generate the reports for the appropriate political oversight bodies. This information is also used to project necessary system improvements and upgrades.

Management and administrative interaction with dispatch and fleet maintenance supervisors is typically limited to oversight. They ensure the respective groups are managing budgets and performing acceptably, as well as providing feedback regarding future system needs. In addition, they interact with the various City of Lincoln and Lancaster County groups, as well as managers of other integrated systems, sharing information about system performance, and planning future system management and improvement strategies.

3.6 Support Environment

The proposed system is primarily an automated system, utilizing AVL, MDTs, two-way radio, and Plain Old Telephone System (POTS) infrastructure to share information between various user classes. Although routine communication is automated, human communication exists; it is expedited by the various automated systems.

As mentioned previously, the IT, radio, and telecommunications user class supports the proposed StarTran AVL system as well as the associated communication and reporting systems according to accepted industry practices. This includes regularly scheduled maintenance along with accepted capital replacement cycles. The support activities for the information and communication systems are performed within the existing StarTran, City of Lincoln, and Lancaster County facilities utilizing existing equipment.

The bus fleet is supported by the fleet maintenance user class. This includes regularly scheduled maintenance according to manufacturer recommendations, as well as daily vehicle washing. Capital replacement is performed on an as-needed basis, utilizing increasing support expenditures as an indicator for scheduling replacement vehicles. The support activities for fleet maintenance are performed within the existing StarTran facilities utilizing existing repair equipment.

4 INFORMATION VIEWPOINT

The Information Viewpoint provides the system developers and other interfacing systems developers with an overview of the data schemas and data flows for the AVL system. Figure 2 shows a high-level diagram of the data schemas and data flows. The final schemas and data flows will be determined by the final system provider when the system is purchased. The information schemas and data flows are marked to indicate whether they are associated with functions that are considered required, desired, or optional. Items on the left side of the figure represent schemas and flows on the vehicles, and the items on the right represent schemas and flows resident in the dispatch center.

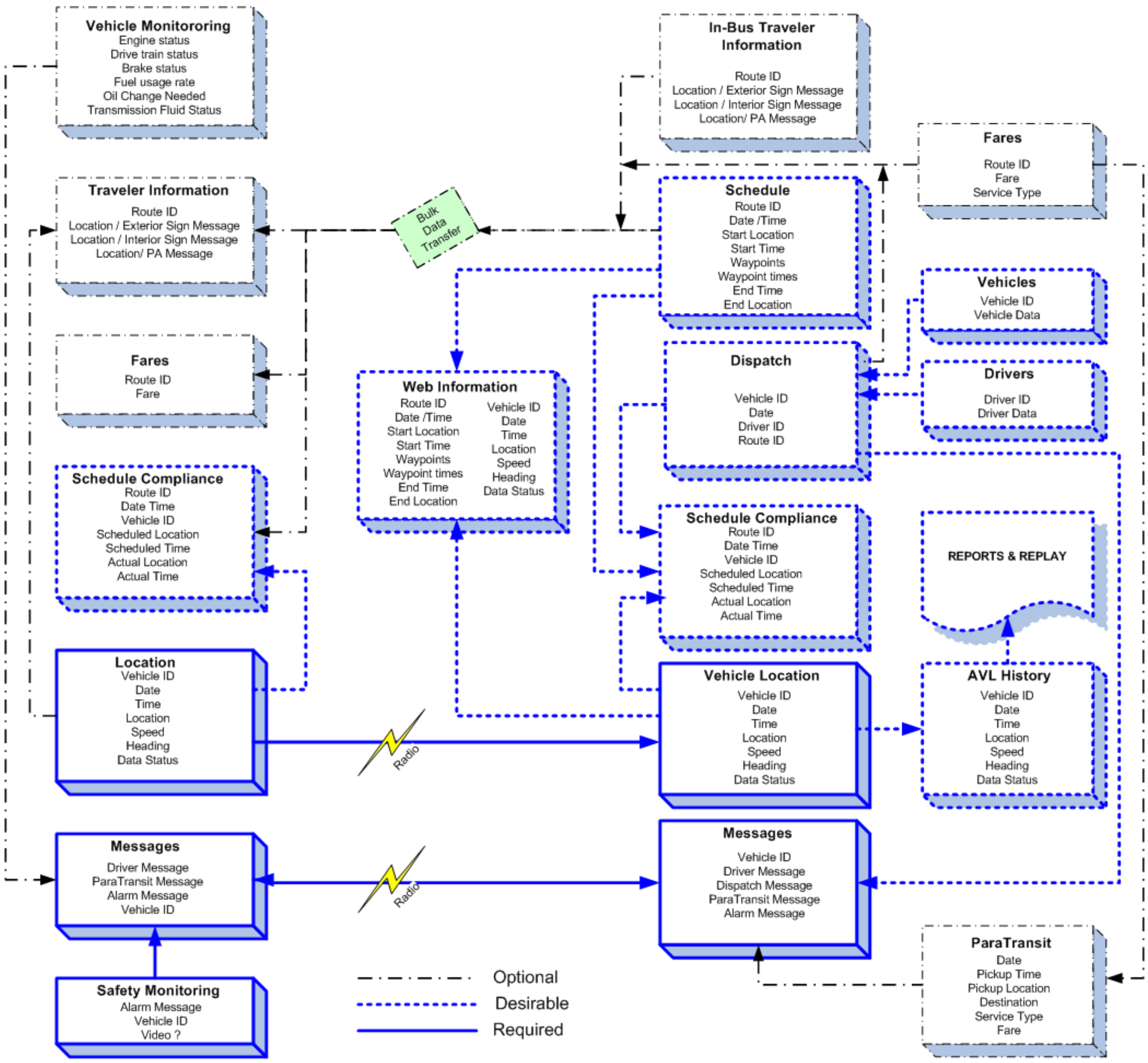

Figure 2 - Information Viewpoint

4.1 *Essential Functions*

The information schemas for vehicle location systems are shown as the ***Location*** and ***Vehicle Location*** tables in Figure 2. This information set is defined by the NMEA-

0183 standard and the information flow is a straight-forward transfer of the information from the vehicle to the dispatch center via a wireless link. The amount of data transferred is only about 64 bytes, but with addressing and error correction overhead the final message is more like 128 bytes long. For 75 vehicles reporting every 15 seconds, this will require about 5.8 Kbps of data bandwidth. If the number of vehicles grows to 300 vehicles, the required data bandwidth grows to 23 Kbps. Options for wireless data transport are discussed in section 7.2 of this architecture.

The panic button alarm within the safety monitoring equipment also represents a well defined message and will require a wireless link. Since the alarm and the covert listening functionality will require tight integration with the existing Enhanced Digital Access Communication System (EDACS) radios, it is presumed that the alarm and all voice communications between the bus and the dispatch center will continue to use the EDACS radio system.

The video collected by the Safety Monitoring equipment presents a special information issue. Full motion video requires a bandwidth of 250 Kbps even after the video has been compressed using the best (MPEG-4) streaming digital compression. By using a Motion-JPEG (M-JPEG) compression and dropping the frame rate down to 15 frames per minute the bandwidth requirements can be reduced to 9.6 Kbps. Three companies have done field demonstrations of systems that use a small single-board computer to convert the video to a compressed, digital video data stream that can provide low-frame-rate video over a cell phone internet connection. These systems use MPEG-4 or M-JPEG standard video formats. This technology could be adapted to use a conventional radio channel to transmit video from one bus at a time, but this option is not offered commercially at this time.

4.2 Desirable Functions

The addition of the “desired” functional capabilities adds significant complexity to the information view of the system.

Route and schedule adherence tracking implies that there is a planned route and a schedule in the system that can be used to compare with the actual route and schedule of each vehicle. In StarTran’s case, there is no existing automated source of the planned route and schedule information in a format that can be exported to the AVL system. To meet this requirement, the AVL system will need to include enough of a scheduling system that the planned routes and schedules for each route can be created and stored in the system. The AVL system will also need enough of a dispatch system to allow vehicles to be assigned to routes so that the AVL data for each vehicle can be compared to the appropriate planned route and schedule. Presentation of compliance information to the bus operator requires the same comparison of actual versus planned. The vehicle operator can obtain the compliance information on an MDT in one of two ways:

- The planned route and schedule can be loaded on a computer in the bus. The current location information from the Global Positioning System (GPS) would be connected to the bus computer, which would use compliance software to calculate and display the route and schedule compliance information to the vehicle operator. This approach requires an MDT with the capability to run compliance software, and a way of performing a bulk data load of the day’s planned schedule and route.

- The route and schedule compliance information can be calculated at the dispatch center and sent to the MDT on each bus on a periodic basis. This approach requires less equipment on the bus, but places a substantial burden on the trunked radio system. Depending on how often the compliance information is updated, this approach would require a minimum of one dedicated data channel for the compliance information alone.

Implementing MDTs in the buses does not increase the information complexity of the AVL system, but does imply that the AVL system will be able to address, send, receive, and route messages. This is similar to the instant messenger software on many computers. Like instant messenger programs, the software and protocols are, to varying degrees, proprietary.

Traveler Information is shown in the center of Figure 2. Schedule and route information would be published from the AVL system to the city's web server in an XML file using the NTCIP 1404 standard for the data content. This file can be used to present schedule and route information on the city's website, and can be re-published to other organizations that need the schedule and route information in a standard format. The vehicle location data would be published from the AVL system to the city's website in NMEA-0183 text format. This information could be used to drive a map on the city's website, or made available to a service such as Next Bus, which could publish the map and next arrival times for the bus system. The web information files contain the information necessary to drive the desired traveler planning system.

The information shown for Vehicle Monitoring is preliminary. The actual data will be dependent on the vehicle area network on the buses, and the instrumentation and automation systems currently installed on the buses. While the vehicle network interface is a standards-based interface, only MDTs specifically designed for this type of vehicle will likely have the necessary interfaces and software to display the information on the bus. The current radio system does not have the capacity to support real-time transmission of this data to dispatchers and maintenance staff, so some sort of bulk data transmission capability will be required to collect the maintenance data.

The desired statistical reporting may be supported in part by the AVL History data. Some key elements of the statistical reporting are not available in the history data, including ridership on each leg of a run and fare data. These data elements, the source for the data, and the interfaces between the sources and the history data repository will need to be defined during the design of the final system.

4.2.1 Optional Functions

Most of the optional functionality deals with additional systems added on the buses.

The automated bus operator login would involve using a driver card to transfer data to the bus, including bus route, schedule, assigned vehicle operator, and fare data. ADA compliant announcement equipment would also use the driver card to assign the messages for internal and external bus signs, and the locations and content of announcements for the public address system. The bus annunciator system would coordinate messages by obtaining current bus location data from the geographic location system in NMEA-0183 format. An automated fare payment system would also be dependent on a driver card or other data transfer scheme to obtain fare updates, and to transfer transaction information back to the dispatch center.

The traffic signal priority services are dependent on the data collected and calculated by the schedule adherence function and are also dependent on the ability of the CAD system to transmit a message to the vehicle to activate the traffic signal priority transmitter.

5 SOFTWARE VIEWPOINT

The Software Viewpoint provides the system developers and other interfacing systems developers with an overview of the computational objects (software modules), program interactions and behavior, and software interfaces that form the system. Figure 3 shows a high-level view of the software modules comprising the complete deployment. This is a conceptual view, and the final design may use different collections of software modules to perform the same functions. The vehicle based software components are in the left hand column.

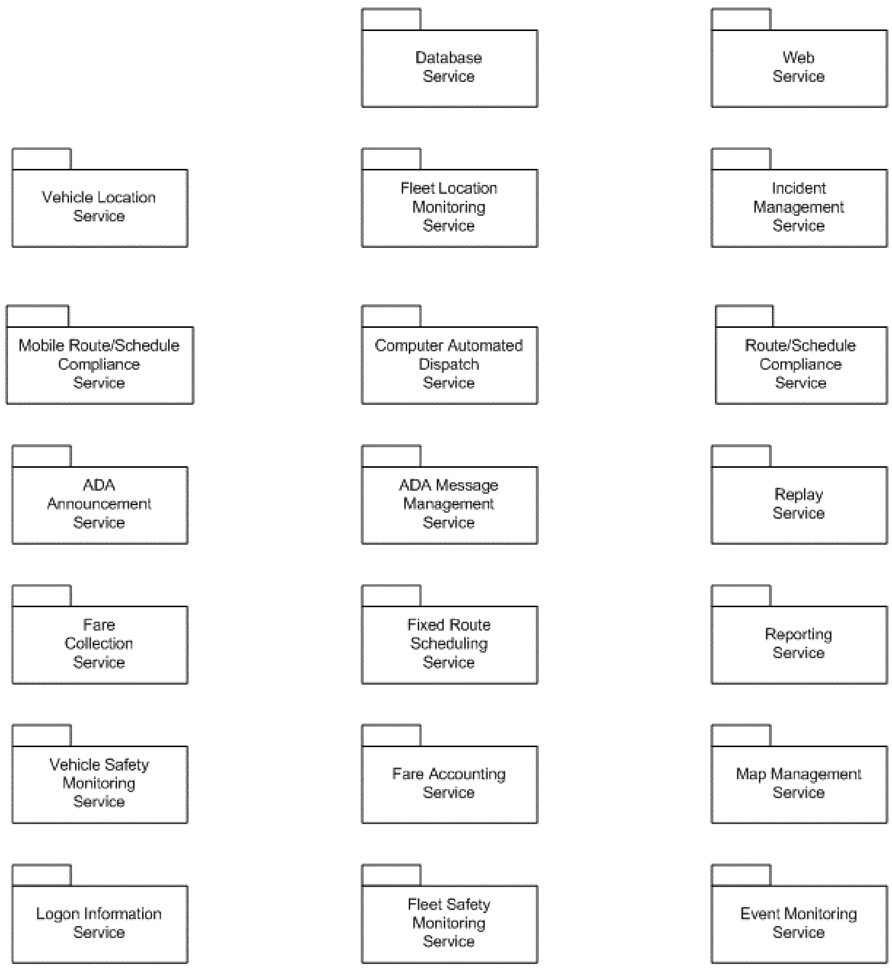

Figure 3 - Software Viewpoint for AVL Deployment

The following sections will identify the software modules associated with each of the functions for the system, and the dependencies between the modules.

5.1 Essential Functions

5.1.1 Vehicle Location Tracking

Vehicle location tracking is based on a calculation of the vehicle location using the GPS system and transferring the information to the dispatch center for display and archival. Figure 4 shows the dependencies between the software components that support the AVL function.

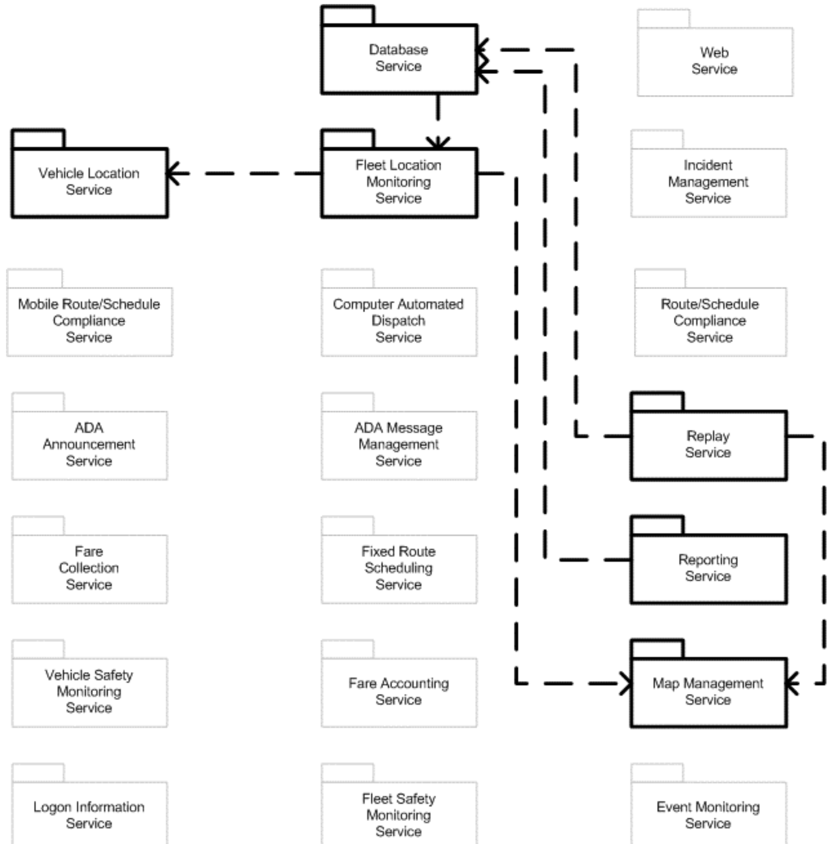

Figure 4 - AVL Software Viewpoint

The AVL functions are performed by a service on the vehicle and a corresponding service at the dispatch center. The vehicle GPS information is logged in the database service. The dispatcher displays can be driven from the database or the fleet location monitoring service. From the archived data, reports and replays of the data can be performed using a reporting service and a replay service. Both the fleet location monitoring service and the replay service are dependent on maps, which are brought into the system and managed using a map management service.

5.1.2 Safety Monitoring Systems

The safety monitoring system provides a way for a vehicle operator to signal an emergency, and for the dispatcher to receive the emergency message and turn on audio and video feeds from the vehicle so that the dispatcher can monitor the situation. Figure 5 shows the software modules that support the safety monitoring functionality and the dependencies between the modules.

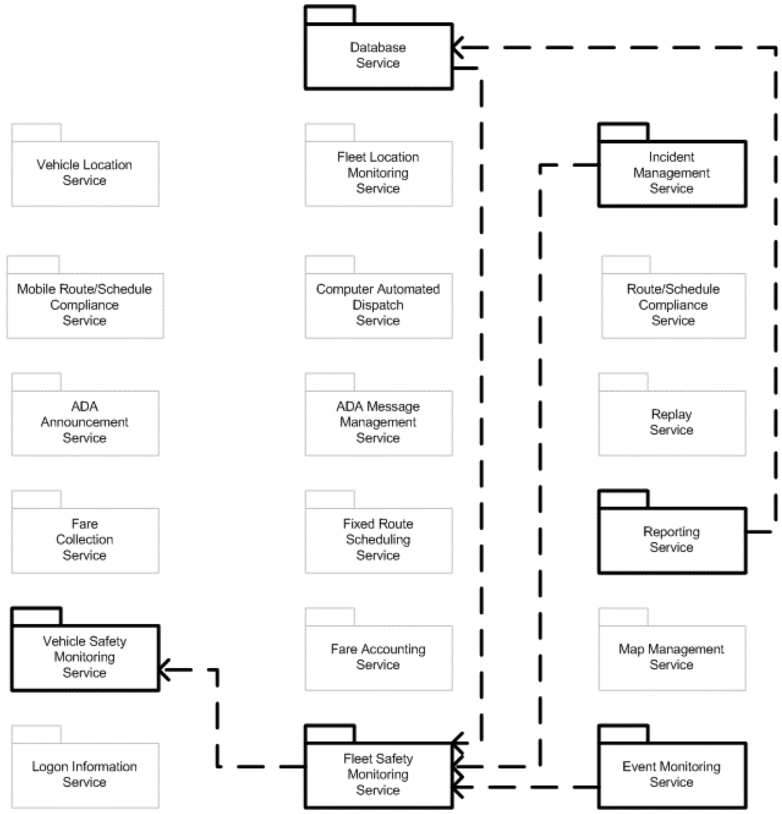

Figure 5 - Safety Monitoring Software Viewpoint

The vehicle safety monitoring service on the bus is responsible for communicating a message back to the dispatch center when the panic button contact is closed. This service is also responsible for activating the video and audio feeds from the vehicle back to the dispatch center.

The fleet safety monitoring service at the dispatch center listens for emergency messages from all vehicles, and sounds an alarm when an emergency message is received. This service also logs the message to the database and provides the message to the incident management service and the event monitoring service.

Reports on safety events are derived from the data in the database.

5.2 Desirable Functions

5.2.1 Route and Schedule Adherence Tracking

The route and schedule adherence tracking system provides a way for the vehicle operators and dispatchers to monitor how well the bus is maintaining its schedule and route coverage. Figure 6 shows the software modules that support the route and schedule adherence tracking functionality and the dependencies between the modules.

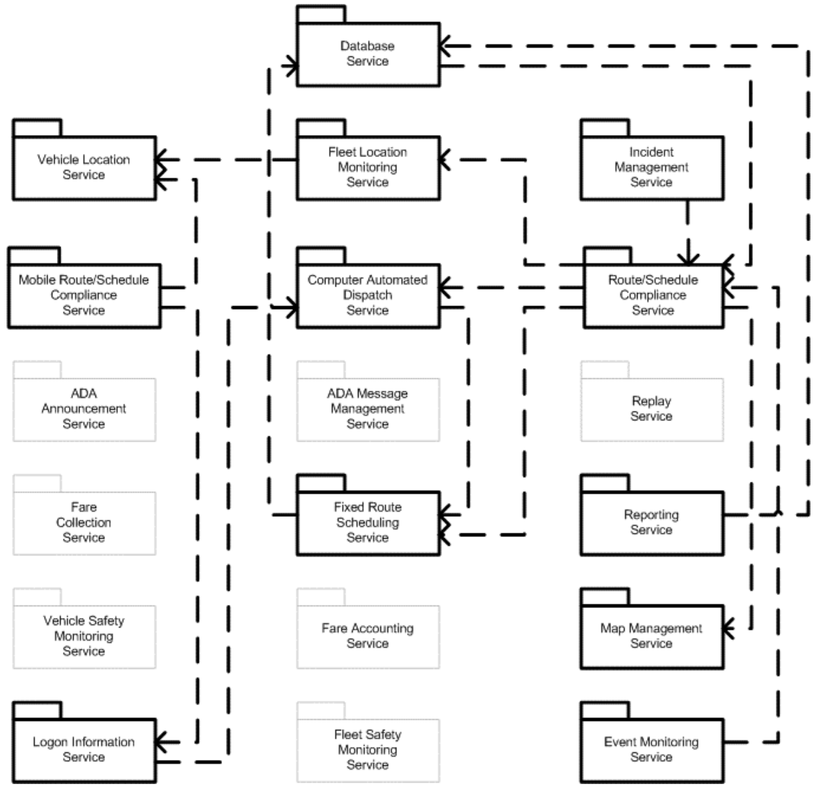

Figure 6 - Route and Schedule Adherence Software Viewpoint

The route and schedule adherence function is dependent on four pieces of information:

- The current location of the vehicle;
- The current time;
- The planned location of the vehicle (route); and
- The planned times the vehicle should be at given locations (schedule).

The first two items of information come from the GPS and the vehicle location service on the vehicle. The last two bits of information come from the fixed route scheduling service. Route adherence is calculated by comparing the current vehicle location with valid locations for the vehicle (the route) and determining how far off the route the vehicle may be. Schedule adherence is calculated by comparing the time the vehicle passes each waypoint on the route with the time that vehicle was scheduled to pass the waypoint and determining how early or late the vehicle is, compared to the schedule.

Since the current location and time information resides on the bus and the planned location and time data resides in the scheduling service, it is a fundamental requirement that these sets of information be brought together for the adherence calculations to occur. Most systems are designed to keep communications between bus and dispatch center at a minimum. This means that the calculation is performed on the bus and also at the dispatch center. The bus transmits location data to operations and the route and schedule data are loaded on the bus at the beginning of the service.

Thus the calculations on the bus (the mobile route/schedule compliance service) are dependent on the logon information service to acquire the route and schedule information. The logon service acquires the information from the computer automated dispatch service, where the operator and vehicle are assigned to a particular route for a given time. The route and schedule data come from the fixed route scheduling service which stores the information using the database service.

The calculations at the dispatch center are performed by the route/schedule compliance service. This service obtains the vehicle locations from the fleet location monitoring service, which in turn depends on the bus vehicle location service for the information. The planned route and schedule data is obtained from the fixed route scheduling service.

Map information for the compliance service comes from the map management service.

When a vehicle exceeds preset limits for schedule or route compliance, the service sends a message to the incident management service, the event monitoring service, and the database service.

Any reporting on compliance is performed by the reporting service using data from the database service.

5.2.2 Mobile Data Terminals

The primary MDT functions are the exchange of text messages with other vehicles or the dispatch center. Figure 7 shows the software modules that support the mobile data terminal functionality and the dependencies between the modules.

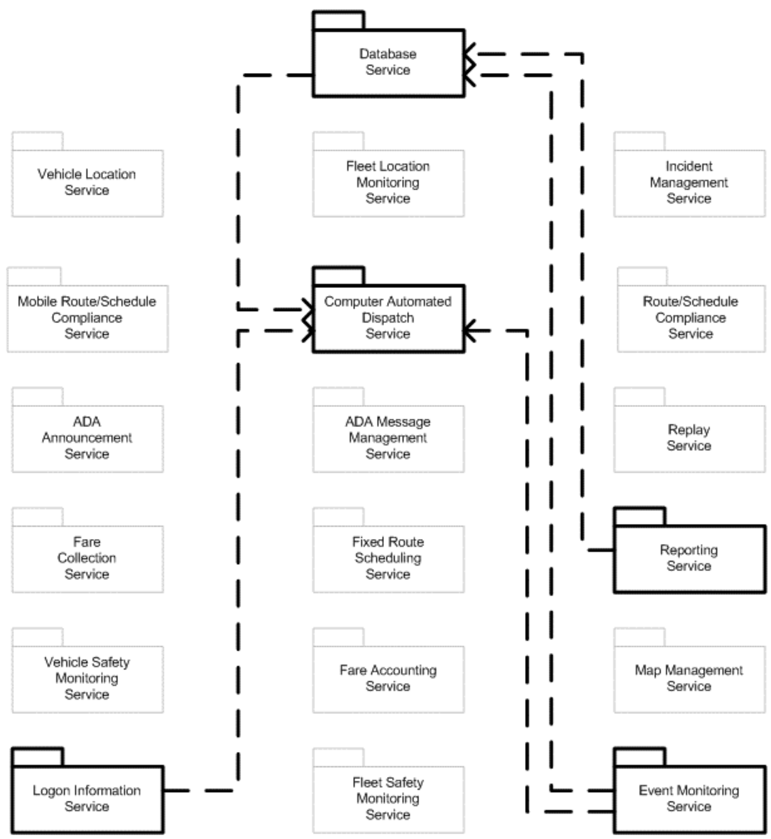

Figure 7 - Mobile Data Terminal Software Viewpoint

The MDT function is primarily a messaging service between the logon information service on the bus and the computer automated dispatch service at the dispatch center. Messages between vehicles are also accommodated, usually by routing the messages through the CAD system.

Messages are logged to the database service and the report service can extract the messages from the database service for reporting. Certain types of messages will also be sent to the event monitoring service which tracks events and the operations actions taken in response to the event. This data is also logged to the database for future reporting.

5.2.3 Traveler Information System

The traveler information system presents the bus route and schedule information from the scheduling system and the information about the current locations of buses and makes this information available to users of the Internet, 511™ traveler information systems, and other travel information outlets. Figure 8 shows the software modules that support the traveler information functionality and the dependencies between the modules.

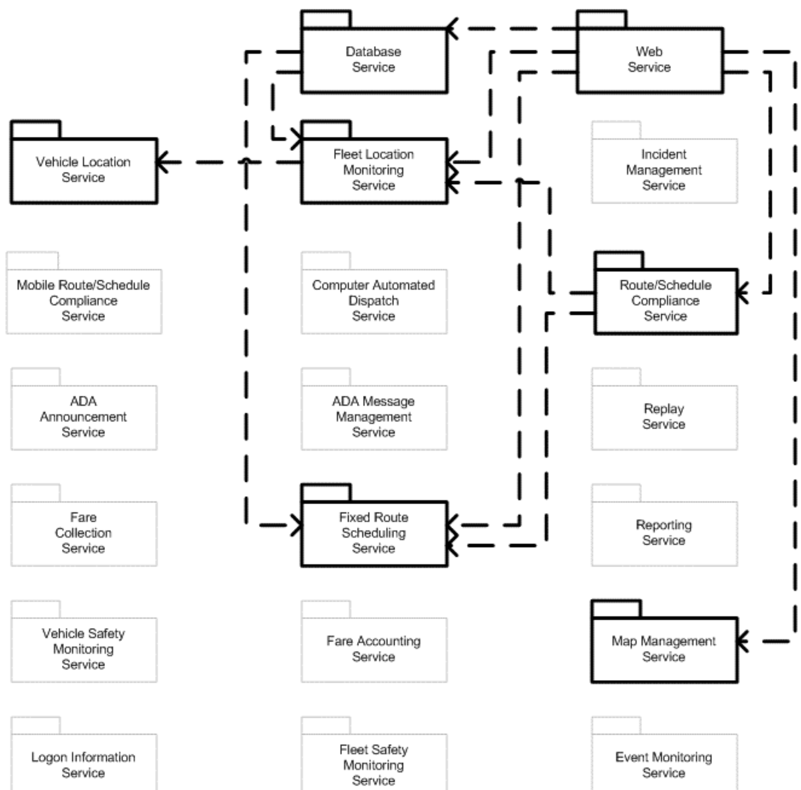

Figure 8 - Traveler Information Software Viewpoint

The web service obtains the route and schedule information from the fixed route scheduling service, or from the database (which obtains the data from the fixed route scheduling service).

Information about the current location of vehicles can be obtained directly from the fleet location monitoring service in the form of a text file using the NMEA-0183 standard RMC message format. The vehicle route and schedule information will be published from the fixed route scheduling service in a XML file using the NTCIP 1404 standard for schedule information. This format support information sharing with 511 systems and other external traveler information systems.

Information about when buses will arrive at their next stop would come from the route/schedule compliance service. There are no current standards for this type of data exchange.

Maps for the web service would be maintained through the map management service. The city currently maintains this type of data in standard ESRI shape files.

5.2.4 Vehicle Component Monitoring

The vehicle component monitoring system tracks the running status of critical vehicle systems (like oil level and engine temperature) and facilitates collecting routine information like odometer readings. Figure 9 shows the software modules that support the vehicle component monitoring functionality and the dependencies between the modules.

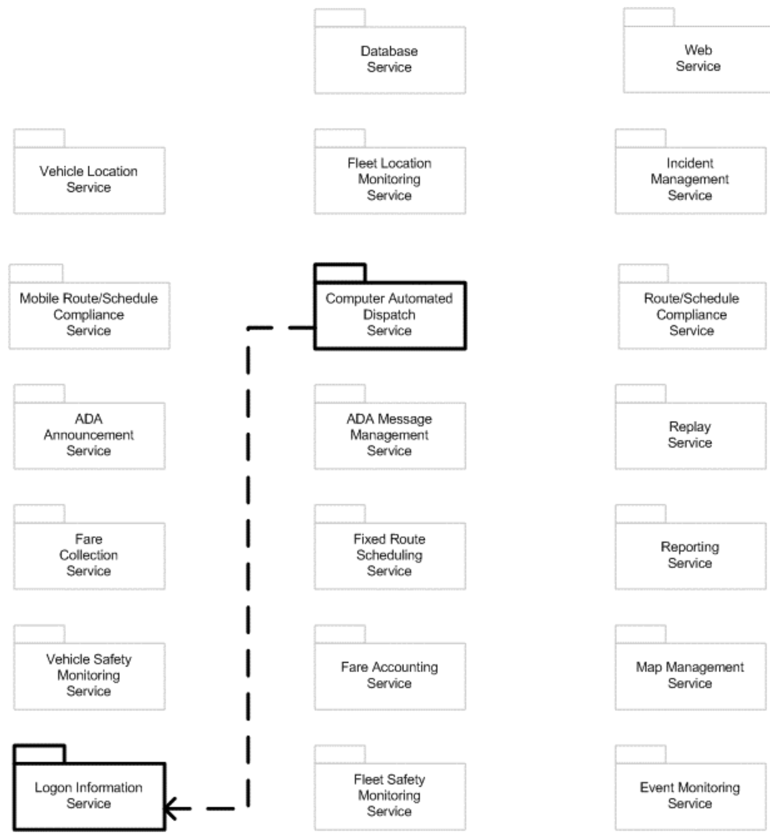

Figure 9 - Vehicle Component Monitoring Software Viewpoint

The vehicle component monitoring functionality is performed primarily by the logon information service. The vehicle equipment information is published on the in-vehicle network which is connected to the MDT running the information service. The information service can display the vehicle condition information to the operator on the MDT.

If the vehicle equipment signals an alarm condition, the vehicle data is transferred to the CAD system where operations staff can view the vehicle condition and make any necessary decisions.

Under normal conditions, vehicle condition data will be stored on the vehicle and reviewed at the end of the day using a laptop or wireless connection to transfer the data from the vehicle to the maintenance operations staff.

5.2.5 System Statistical Reporting

Reporting functions on the AVL system are intended to reduce the work effort in preparing various reports for management and federal oversight.

All reporting functions are dependent on the required data for the report residing in the database. If the data is not collected automatically by some service and placed in the database, then a manual data entry process will be required to enter the required information into the database. Figure 10 shows the software modules that support the system's statistical reporting functionality and the dependencies between the modules.

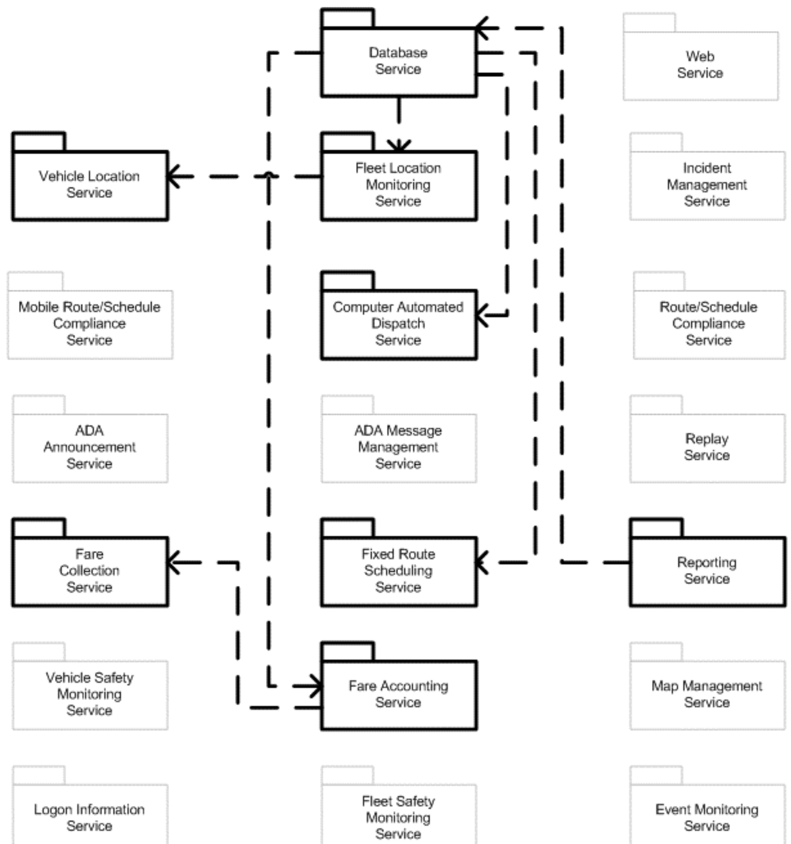

Figure 10 - Statistical Reporting Software Viewpoint

The reporting service is dependent on the database service for all report information. The database service obtains vehicle location information from the fleet location monitoring service, which in turn collects the information from the vehicle location service running in each vehicle. The database service obtains vehicle/route assignments from the CAD service. Fare and ridership data is acquired from the fare accounting service, which is dependent on the vehicle fare collection service for the information. Route and schedule information is acquired from the fixed route scheduling service.

5.3 Optional Functions

5.3.1 ADA Compliant Announcements

The ADA compliant announcements and driver login function provide an automated mechanism for providing traveler information to patrons on the bus. The ADA announcement service controls the destination message on the external bus head sign, and next stop destination and times on internal electronic signs for the riders. The system also provides audio messages for the vision impaired at appropriate points along the route to supplement the on-board signs. Figure 11 shows the software modules that support the ADA compliant announcement functionality and the dependencies between the modules.

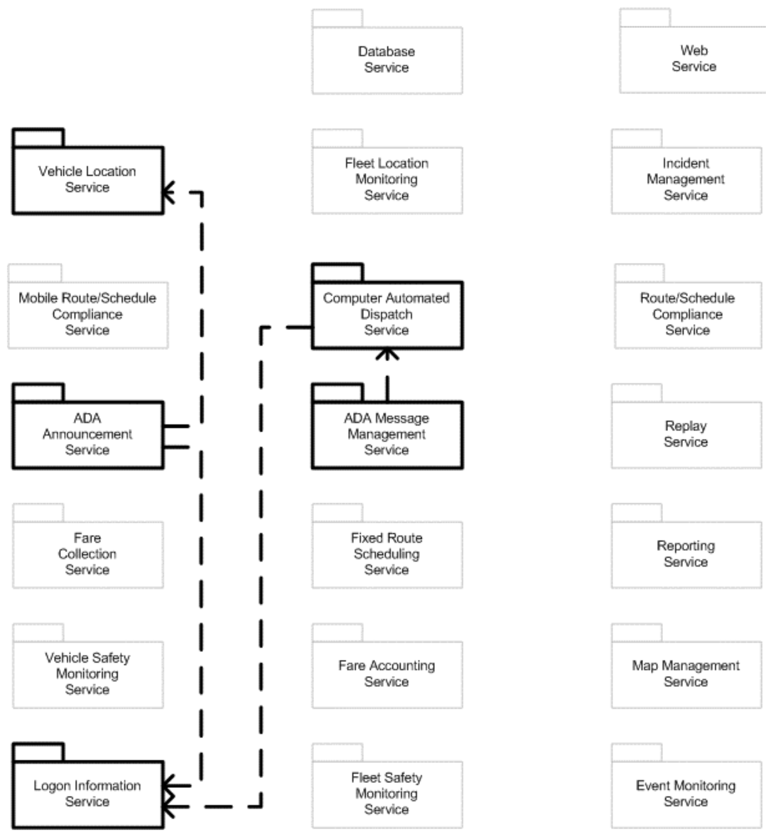

Figure 11 - ADA Announcements Software Viewpoint

The ADA announcement service needs the following information to function:

- The current location of the vehicle;
- The bus route, including all critical waypoints; and
- The messages for the head sign, internal signs and public address system for each waypoint along the route.

The current location of the vehicle is provided by the vehicle location service in a NMEA-0183 message.

The route and message information comes from the logon information service, which is dependent on the CAD service and the ADA message management service for the information. This information is usually in a proprietary format, requiring close integration between the announcement service, the logon information service, CAD service, and the ADA message management service.

5.3.2 Fare Payment System

The fare payment system enables the use of automated cards for fare transactions. This service also serves the function of collecting ridership information along the routes. Figure 12 shows the software modules that support the fare payment functionality and the dependencies between the modules.

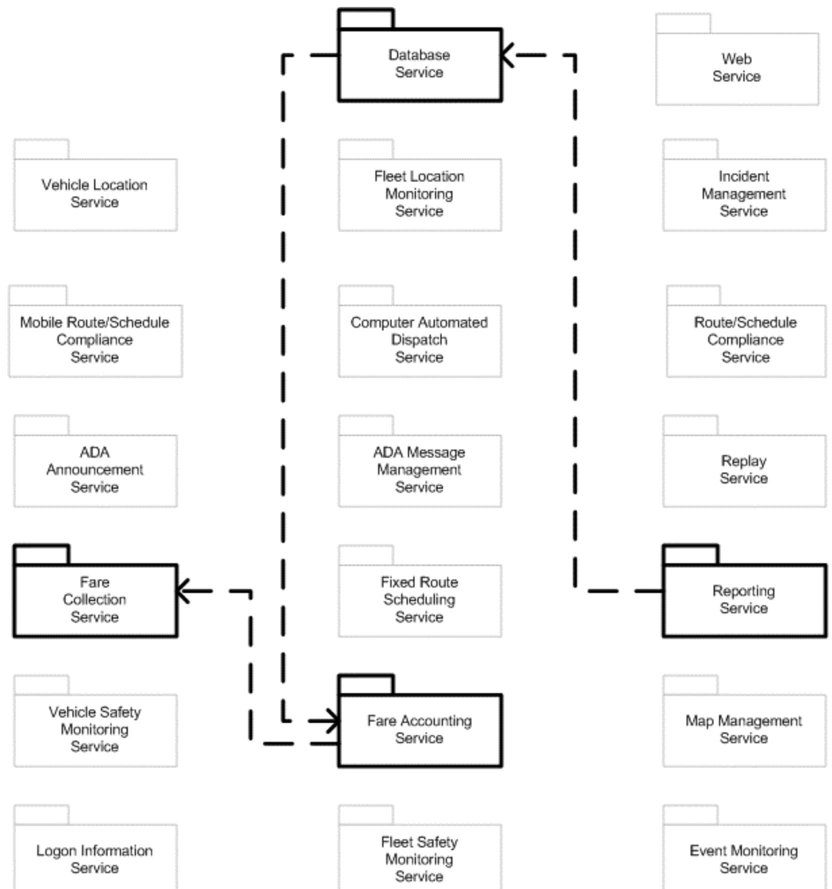

Figure 12 - Fare Payment Software Viewpoint

The fare collection service on each vehicle is the critical element for this functionality.

The fare accounting service depends on the fare collection service for data. There is a smaller, infrequently used pathway from the fare accounting service that allows the rates to be set in the fare collection service.

The accounting service stores all of the information it collects in the database service. Reports generated by the reporting service are dependent on the data in the database.

5.3.3 Traffic Signal Priority

The traffic signal priority is intended to improve schedule adherence by reducing travel times through signalized intersections when a bus is running behind schedule. Figure 13 shows the software modules that support the traffic signal priority functionality and the dependencies between the modules. It should be noted that this functionality will require close coordination with the City of Lincoln's Public Works & Utilities Department, which is responsible for the signal systems.

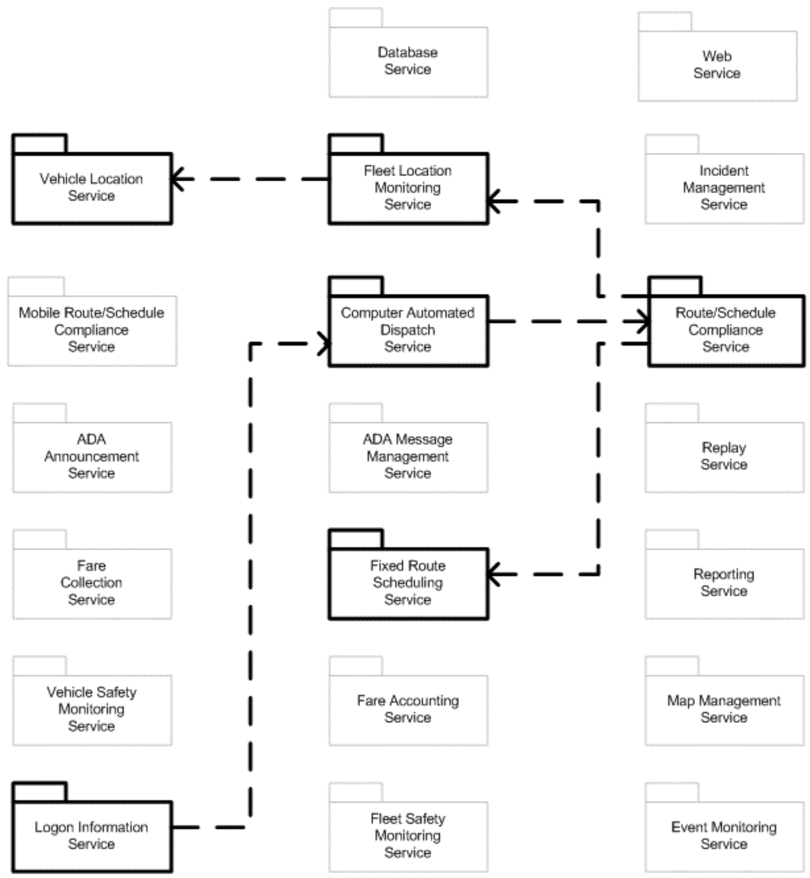

Figure 13 - Traffic Signal Priority Software Viewpoint

This functionality is usually achieved by equipping the revenue vehicles with the same kind of transmitters that the police and fire vehicles use to initiate traffic signal priority. To keep the vehicle operators from abusing the capability, the transmitter is controlled by a contact output under the control of the logon information service.

The logon service receives the control signal from the CAD service, which in turn receives the signal from the route/schedule compliance service. The compliance service is programmed to send the control signal when a revenue vehicle is more than X minutes behind schedule, with X being an administratively controlled variable.

As noted previously, the route/scheduling compliance service is dependent on the fixed route scheduling service for route and schedule information, the CAD service for vehicle/route assignment data, and the vehicle location service and fleet location monitoring service for current vehicle location, direction of travel, and speed data.

6 HARDWARE VIEWPOINT

The Hardware Viewpoint provides the system developers, communication system designers, network system designers, hardware designers, and system maintenance and support staff with an overview of the planning for the hardware, communications, and operational support for the system.

Figure 14 shows the hardware for the essential, desired, and optional functions of the AVL system. The yellow boxes on the left side of the figure represent equipment that would be installed on StarTran vehicles, and the blue shaded boxes on the right represent fixed-base equipment and infrastructure supporting StarTran operations. Blocks that are placed directly against each other represent components that are likely to be tightly integrated, usually integrated with proprietary interfaces.

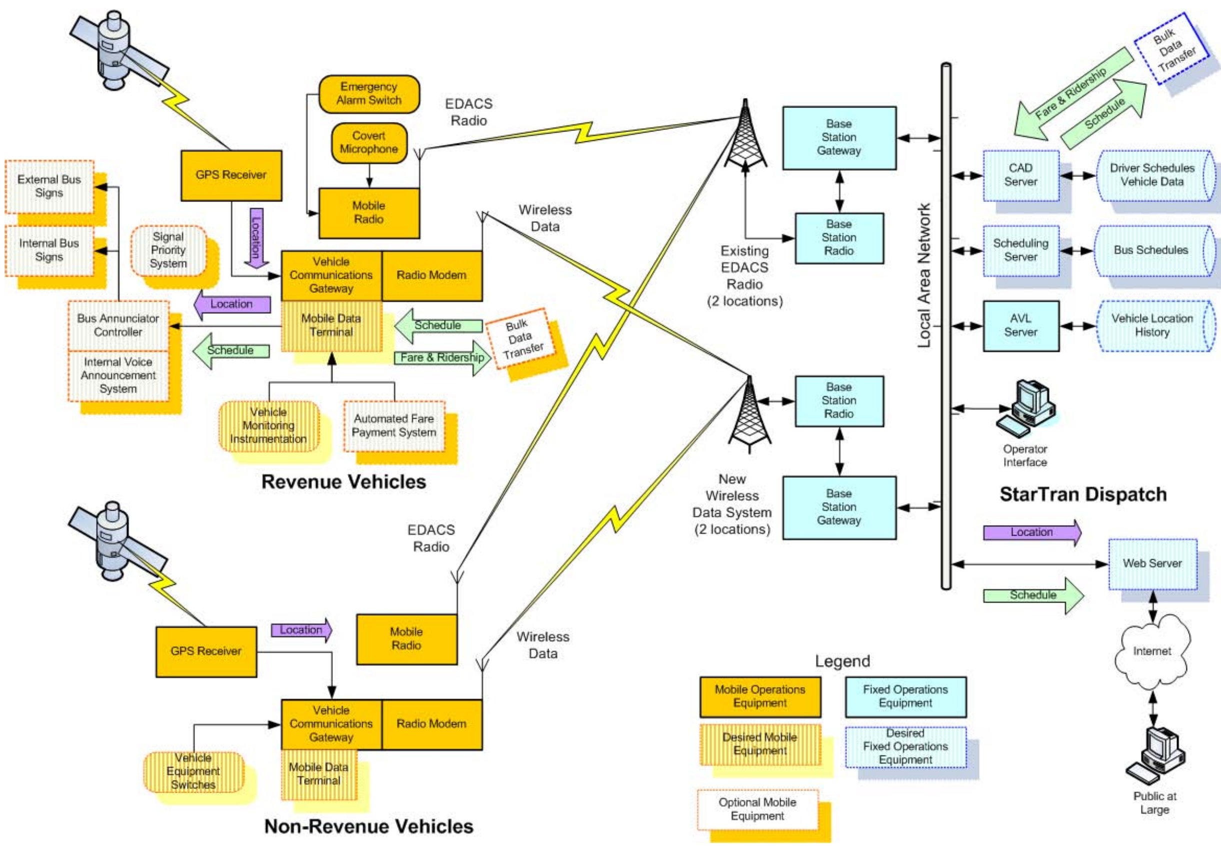

Figure 14 - AVL System Hardware Viewpoint

The three servers on the right represent separate functionality, but from a hardware standpoint these could be combined or deployed separately on one, two, or three servers. While only one operator console is shown, multiple consoles, located at any point on the network backbone, could be supported. The web server shown could be the existing city web server, a new server, or a combination of the city's existing server and external commercial web servers.

The mobile radios, associated base station radios, and base station gateway represent existing EDACS trunked radio equipment. The base station radios, gateway, and local area network are city owned, maintained, and operated. The existing mobile radios are owned and operated by StarTran, and maintained by the city. The current concept will require purchase of additional wireless data equipment to connect AVL components in the vehicles with AVL components in the dispatch center. It may also be necessary to replace the mobile radios with new radios equipped with connections for the emergency alarm switch and the covert microphone.

The GPS satellites are also existing infrastructure, owned, maintained, and operated by the Federal government. There are no use-fees associated with use of the GPS system.

6.1 Essential Functions

6.1.1 Vehicle Location Tracking

On the operations side, the AVL server receives NMEA-0183 messages and displays the vehicle location information on a background map on the operator workstations.

The hardware required on a vehicle for basic vehicle location capabilities include the GPS receiver, vehicle communications gateway, and radio modem. Most gateways can accommodate trunked radio, conventional radio, cellular modem, and Wi-Fi wireless radios.

The GPS receiver calculates the vehicle location based on radio signals received from three or more GPS satellites. The accuracy of the location fix is dependent on the quality and number of satellite signals, and the quality of the receiver. Fix accuracy can range from 100 meters to 1 meter, with the more expensive receivers usually yielding the higher accuracies.

6.1.2 Safety Monitoring Systems

The vehicle communications gateway will usually be equipped for contact inputs, contact outputs, and in some cases, analog inputs. The emergency alarm switch is connected to one of these inputs and programming on the AVL server is set up to recognize this contact closure as an alarm condition. The covert microphone is usually wired directly into the radio transceiver, but a contact output from the gateway may be used to control keying for the microphone. Many mobile data terminals include the emergency alarm switch and covert microphones as a part of the mobile data terminal.

Most manufacturers integrate the vehicle communications gateway with the radio modem and offer different models of their gateway, depending on the type of radio that will be used. Several manufacturers integrate the GPS receiver, the radio transceiver, or both as a complete gateway package for AVL. If StarTran accepts these more tightly integrated packages, it could substantially impact the choices of equipment for other future (non-transit) users of the AVL system.

Figure 15 shows a basic block diagram for the hardware required to support a safety monitoring video feed from a bus to the dispatch center. The video cameras are currently connected to an on-bus recorder. This video feed would be split and connected to a small computer. It would also be possible to install new cameras specifically for this feature. The computer would convert the video to a compressed, digital format. The digital format could be either M-JPEG or MPEG-4. When the computer receives a trigger signal from either the dispatch center or the bus panic switch, it would begin transmitting the digital video feed through a wireless connection. The commercial versions of this product use cellular radio modems and present the video on a web page, accessible through the Internet. Security on the web page prevents un-authorized viewing of the video.

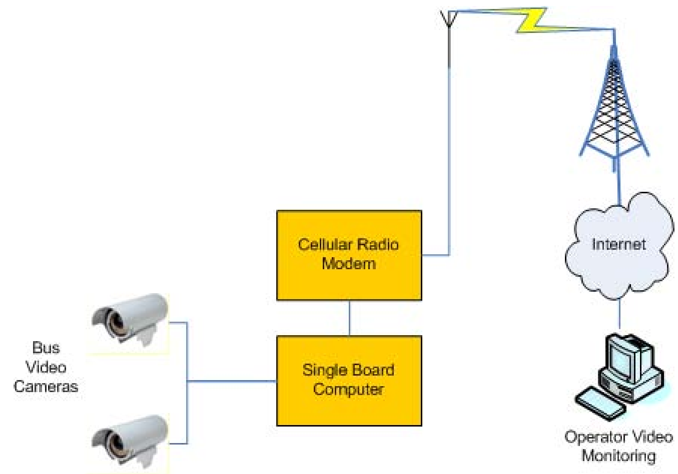

Figure 15 - Video Surveillance Hardware Viewpoint

6.2 Desirable Functions

6.2.1 Route and Schedule Adherence Tracking

The desired route and schedule adherence tracking functions will require the addition of CAD and scheduling servers in the dispatch center. Depending on the software purchased, this could be two separate servers or one server. It may also be possible to combine the CAD, AVL, and scheduling on one server.

No additional hardware is required on the bus for this feature, unless the vehicle operator needs to view the compliance information.

If the operator needs to view the compliance information, then the minimum hardware addition on the bus for this feature is an MDT. This assumes that the AVL server will send compliance data to the bus MDT on a regular basis. Even if these messages are short (less than 128 bytes), the keying time on the radios can limit the number of messages sent per minute. To send data to 60 buses would require about 17-21 seconds at 4800 bps, 10-13 seconds at 9600 bps, and 7-9 seconds at 19.2 Kbps.

If an MDT with bulk data transfer capability is installed on the bus, the planned route and schedule information could be transferred to the bus, and the compliance information calculated on the bus. This would allow the vehicle operator to have real-time compliance information without using air-time on the radio system. Most commercially available transit route and schedule adherence tracking systems use this method. Options for bulk data transfer include using the primary wireless data connection (only if it has the necessary bandwidth), using a Wi-Fi connection between the MDT and a Wi-Fi hotspot at the main bus terminal, or using a data card and card reader attached to the MDT.

6.2.2 Mobile Data Terminals

The MDTs of today are more that just terminals; they are usually small personal computers packaged for a rugged environment. The MDTs represent an integration point for several other desired and optional functions. While the MDTs and vehicle communication gateway were tightly integrated in the past, the current trend is moving to an open interface between the MDT and the gateway. This is because the gateway/modem equipment requires maintenance and technology updates at a less frequent rate than the MDTs. Most MDTs now connect to the gateway with a serial RS-232 or TCP/IP standard interface.

The MDTs for the revenue vehicles should be equipped with interfaces for the ADA announcement system, vehicle monitoring system, fare collection system, and card reader even if these devices are not purchased immediately. The ADA interface will be a standard serial interface using either RS-422 or RS-232.

A card reader is likely to be tightly integrated with the terminal, to the extent that StarTran will likely have the option of purchasing an MDT with an integral card reader, or an MDT without a card reader. Many MDTs will also include integrated covert microphones for safety monitoring and the radio equipment for voice and data connections to the dispatch center. Such tightly integrated MDTs should only be considered if they offer a standard, open protocol for communications to the dispatch center. If a proprietary protocol is used, StarTran could lock itself, and other city agencies into a sole source situation for the vehicle equipment.

Implementing Wi-Fi on the MDTs is usually less problematic. PCMCIA slots on the MDT will allow off-the-shelf Wi-Fi adapters to be added or changed out later for WiMAX adapters. See Sections 7.2 and 7.3 for more information about communications options.

6.2.3 Traveler Information System

The traveler information system hardware will be comprised of a web server and the necessary network infrastructure to connect the server to the StarTran local area network and to the Internet. The current concept is to use the existing city web server for the traveler information system. The server would receive information from the AVL system over a 100MBps Ethernet connection.

6.2.4 Vehicle Component Monitoring

The vehicle component monitoring system will require an MDT on each monitored vehicle, which will serve as the vehicle operator display system and as the computational platform for the software to monitor the equipment and sound alarms when conditions merit the attention of the vehicle operator or the maintenance staff. The MDT will require a physical interface that is compatible with the bus internal data network.

6.2.5 System Statistical Reporting

Reporting functions on the AVL system will run on the AVL server or on the city's relational database server. If printed copies of the reports are required, a printer will be needed, either directly connected to the AVL server or on the LAN as a network attached printer.

6.3 Optional Functions

6.3.1 ADA Compliant Announcements

The hardware required for this function includes bus head signs, internal signs, internal voice announcement system, and bus annunciator controller. The annunciator controller may be furnished with internal storage and a user interface, or may depend on the MDT for this hardware. The MDT interface will be a standard serial interface, either EIA RS-232 or EIA RS-422.

The operator login function will require an MDT on each bus. The MDT will require either a card reader or a wireless network connection to the AVL server for data transfer to the bus.

Adjusting the head signs will require that the MDT have an interface directly with the head signs, or with a bus annunciator controller that interfaces with the head signs. The current head signs use a SAE J1857 protocol on a RS-422 electrical interface. Most bus annunciator controllers support SAE J1708, EIA RS-232, and EIA RS-422 interfaces.

The GPS equipment from the essential requirements is also needed to provide location data to the annunciator controller. The GPS interface will be a standard serial interface, either EIA RS-232 or RS-422 and the NMEA-0183 protocol, and RMC message set.

Internal signs for the bus would be provided as a part of this design package and the contractor would be responsible for the interfaces between these signs and the annunciator controller.

Audio feeds from the annunciator controller would connect to the vehicle public address system through existing audio jacks.

6.3.2 Fare Payment System

The hardware required for this function includes card readers and fare-box equipment in each revenue vehicle. Data from the fare collection system can be transferred to the fare accounting system at operations by several means. Most systems support a Wi-Fi data transfer, collection by directly connecting a laptop to the vehicle equipment, or output to disk.

6.3.3 Traffic Signal Priority

The hardware required for traffic signal priority is similar to that installed on fire, police, and other public safety vehicles. The transmitter is controlled by a contact output from the vehicle communication gateway. This approach allows the dispatch center, and not the vehicle operator, to trigger the signal priority transmitter. The transmitter is usually controlled based on the schedule compliance software at the dispatch center, based on how far behind schedule the bus is running.

7 TECHNOLOGY VIEWPOINT

The Technology Viewpoint provides the system developers, communication system designers, network system designers, hardware designers, and system maintenance and support staff with an overview of what relevant technologies will be used, how industry standards and specifications will be implemented, and what technologies will be required to support testing of the system.

7.1 Computer Platforms

Servers are currently maintained by the City of Lincoln and are upgraded or replaced on a three year cycle. The city uses Dell Pentium processor based servers and would prefer to have Dell equipment purchased for this system for ease of support. The city would consider purchasing the server equipment to the contractor’s specifications if this would facilitate the preferred equipment.

Dispatchers currently have 1-2 year old desktop computers which are Dell systems with 2.4 GHz Pentium processors, Windows XP operating systems, and 40 to 80 GB hard drives. The city would prefer to retain these computers and use them for this system.

The city currently uses the Windows operating system predominately, with some Novel servers providing login authentication. The city would prefer software running on Windows 2003 (or newer) for the servers and Windows XP for any laptops and desktop applications. There is not a strong preference for the operating system on the MDTs.

The city currently operates a clustered Oracle database server. Several smaller SQL Server deployments also exist that are specific to applications. The city would prefer to implement any database services on the existing Oracle server, but would consider a SQL Server implementation if the system does not require support from a local database administrator.

7.2 Data Communications

The original concept for the AVL system was to retain the existing EDACS trunked radio system for voice communications between the vehicles and the dispatch center. One or more new wireless channels would be added to the vehicles to support the data communications requirements. Little, if any, data would be transported on the EDACS system.

This basic concept presents one design problem that is not readily apparent at the architectural level discussed in this document. The safety monitoring system functionality presumes a tight integration between the CAD system (which is managing the messages from the vehicle) and the voice radio system. Many MDTs have the emergency alarm switch and the covert microphone built into the MDT, along with the interface for one radio. The radio is presumed to be the radio for both voice and data communication.

There is no technical reason why the voice and data can’t be split and use separate systems. The vendors will consider this design unusual, but most will be able to comply with the requirement to split the data communications off onto a separate system.

7.2.1 Data Communications Options

While some consideration was given initially to using the EDACS system for data, it is obvious from investigations of the existing system and the data requirements for AVL that this is not practical. This leaves five possible wireless solutions:

- Conventional radio in the 800 MHz band
- Spread-spectrum radio in the 900 MHz band
- Wi-Fi
- WiMAX
- Cellular data services

The city operates an extensive TCP/IP network throughout Lincoln, with substantial unused dark fiber. Most of the city's backbone network is gigabit Ethernet on fiber. Most of the above plans will rely on using some of the backbone network and dark fiber to connect base station radios to the city's LAN.

7.2.2 Conventional Radio

The city has obtained licenses for two NPSPAC (narrow band) frequencies for a conventional 800 MHz radio channel. No radios have been purchased for this channel. Implementation would require purchase of two base station radios, a communication gateway, and 800 MHz data radios with modems for each vehicle. The gateway would require a modem and a terminal server to connect the data to the StarTran Local Area Network. Existing fiber would be used to provide a data channel between the base stations and from the data gateway to the city's LAN.

This type of channel typically supports a 4.8 Kbps full duplex data stream, and can sometimes support 9.6 Kbps data streams using special modems. In a digital mode, using an EDACS OpenSky IP gateway, the channel would support 19.2 Kbps data rates.

The GPS and text messaging data will require 5-10 Kbps of the bandwidth on the channel, leaving little or no accommodation for voice, video, or other data traffic. Growth of the system (additional vehicle location tracking for other city vehicles) would be accommodated by adding NPSPAC frequencies for additional bandwidth.

The base station transmitters and gateway for this option would cost about $270,000.

The advantage of implementing an EDACS OpenSky IP Gateway is that the gateway will support both data and voice over the digital channels. Voice uses Voice Over IP (VOIP) technology. The IP Gateway permits the EDACS and OpenSky systems to join together for inter-network communications while using the existing C3 Maestro Console for dispatching on both systems.

7.2.3 Spread-Spectrum Radio

Spread-spectrum radios use a set of unlicensed frequencies in the 900 MHz band to provide data communications with data rates approaching 1 Mbps. Each base station transmitter can provide coverage for a 6 to 7 mile radius. The city would connect the base stations to the existing LAN network using existing fiber capacity throughout

Lincoln. As many as 10 transmitter locations would be required for coverage throughout Lincoln.

This system functions like a cell telephone network, with each transmitter serving as a separate data collision domain. This means that a 10 transmitter system would have an effective bandwidth of 10 Mbps. That much bandwidth would support all of the projected data needs for GPS data, text messaging, bulk data transfer and video.

The base station radio equipment for a deployment of 10 transmitters would cost about $200,000 excluding the costs of any fiber optic equipment required to connect the transmitters to the network. Radios for the vehicles would cost about $2100 each.

The advantage of this approach is that there would be excess bandwidth that could be used by other city departments for mobile data connectivity to the city's LAN.

7.2.4 Wi-Fi

It would be possible to use the city's dark fiber and network backbone to set up a wireless mesh network of IEEE 802.11g (Wi-Fi) hotspots that would serve the voice and data requirements of the AVL system. The IEEE 802.11g technology is already used in several point-to-point short-haul applications to connect parts of the city's network. The technology is also used in several buildings to provide indoor wireless access within the facilities. A mesh network would require access point transmitters about every two blocks. As many as 100 access point locations could be required to provide coverage for the bus routes.

A mesh network also functions like a cell telephone network. The resulting bandwidth would support all of the projected data needs for GPS data, text messaging, bulk data transfer and video.

The access point radios equipment for a deployment of 100 hotspots would cost about $400,000 excluding the costs of any fiber optic equipment required to connect the transmitters to the network. Wi-Fi equipment for the vehicles would cost about $100 each. It should be noted that Wi-Fi equipment may be installed on the MDTs to support bulk data transfer even if a Wi-Fi mesh network is not deployed for the bus routes.

The advantages of this approach are that there would be excess bandwidth that could be used by other city departments, and that the Wi-Fi equipment for the buses and other mobile users is "off-the-shelf" technology and can be purchased at very competitive prices.

7.2.5 WiMAX

A new wireless technology based on the IEEE 802.16 standard (WiMAX) is now licensable, but equipment will not be available for sale until late 2006 or early 2007. WiMAX has a substantially larger coverage footprint (3-15 mile radius vs. 100-300 foot radius for Wi-Fi). In theory, this would allow two transmitter locations to cover most of Lincoln. In practice, supplemental coverage would probably be required in the downtown area where buildings would obstruct the signal path or cause multi-path fading. The Water District for the City of Lincoln is currently planning such a deployment to provide wireless access to city meter readers and field workers. Such a system would have sufficient bandwidth to serve both the Water District and StarTran.

A WiMAX network could provide between 5 and 35 Mbps of bandwidth throughout the city. The resulting bandwidth would support all of the projected data needs for GPS data, text messaging, bulk data transfer and video.

Pricing is not currently available for WiMAX equipment because no vendors have completed the necessary qualification testing to get FCC permission to sell equipment in the United States.

7.2.6 Cellular Data Services

Some of the local cell phone providers offer wireless internet access through cellular data services. Depending on the provider, these wireless internet offerings would be based on standards such a CDPD, GPRS, 1xRTT or EDGE. Each of these standards provides slightly different bandwidth and capabilities. The city is currently evaluating use of 1xRTT services for mobile data service in one or more departments.

- The CDPD standard is being phased out with all providers expected to sunset the technology by the end of 2006. CDPD has a 19.2 Kbps data rate. Verizon is the only national carrier still supporting CDPD
- GPRS offers a 115 Kpbs data rate and supports concurrent voice and data. GPRS has a substantial transmission delay and is not suitable for streaming data applications such as video. When used concurrently with voice, data rates drop to 20-40 Kbps. GPRS is offered by ATT Wireless, Cingular, and T-Mobile.
- 1xRTT offers a 114 Kbps data rate (upload), 300 Kbps (download), and supports concurrent voice and data. When used concurrent with voice, data rates drop to 40-60 Kbps. 1xRTT is offered by Alltel, Sprint and Verizon.
- EDGE is the next generation offering to supplant GPRS. EDGE offers 513 Kbps data rates, with concurrent voice and data. EDGE is not currently offered in Nebraska.

The bandwidth provided by these services would support all of the projected data needs for GPS data, text messaging, bulk data transfer and video.

Pricing for commercial cellular data services is highly volatile. StarTran would qualify as a business user. Rates are usually based on the amount of airtime used and the number of vehicles equipped. For business pricing, the carrier must be contacted. A typical rate will be around $60 per month per vehicle for unlimited data, or about $50,000 per year for the StarTran fleet.

This approach requires no capital investment in radio equipment, but converts the communication cost from a capital cost to an annual operating cost.

7.3 Bulk Data Transfer

Several of the optional functions contemplated for the system require transfers of large amounts of data between the buses and the dispatch center at the beginning and end of each bus run. Three options are considered for this bulk data transfer:

- Digital Smartcards
- Wi-Fi network

- Data Communications

7.3.1 Digital Smartcards

Digital Smartcards are credit card sized devices that can be used as data carriers. These cards are based on the ISO 14443A standard and usually have a data storage capacity of 20 KB or less. Both the dispatch center and each revenue vehicle would need to be equipped with card reader/writers.

These cards are suitable for the driver, route, sign, and fare data transfer at the beginning of each route, but would not typically have the capacity to manage voice recordings for the ADA announcement system. They would have the necessary capacity for the fare, ridership, and mechanical data transfer at the end of each run.

The card readers are typically tightly integrated with the MDT, meaning that StarTran would need to purchase the readers with the MDTs if any future application will require the card reader.

This is the least flexible alternative, with the lowest data transfer capability.

7.3.2 Wi-Fi Network

One or more Wi-Fi access points could be installed at the main bus terminal and any other primary departure points. Each MDT would be equipped with a Wi-Fi card. As each bus is prepared for a run, the bulk data transfer application would transfer the required data from the AVL system server to the bus MDT. At the end of each run the process would be reversed, with the MDT uploading data to the AVL system.

This alternative provides the capacity to manage all of the anticipated bulk data transfer requirements, including voice recordings for the ADA announcements.

Wi-Fi is usually implemented in MDTs by adding a Wi-Fi PCMCIA card to the terminal. This approach makes it easy to add or upgrade the bulk data transfer capabilities for the buses at a later time, as technology changes.

7.3.3 Data Communications

As noted in Section 7.2, several of the data communications systems contemplated for the vehicle to dispatch center data connection have enough bandwidth to accommodate the bulk data transfer requirements.

If one of these systems is selected, the bulk data transfers would be specified and designed to use the primary data communication channels.

7.4 Standards and Specifications

There are several industry standards and specifications applicable to the AVL system. These standards and specifications are shown in Table 1.

Table 1 - Standards and Specifications for the StarTran AVL System

Standard	Description
HTTP	**HyperText Transfer Protocol – Version 1.0 available at: http://www.w3.org/Protocols/rfc2616/rfc2616.html**

Standard	Description
EIA RS-232 RS-422 RS-485	**Three Electronic Industry Association/Institute for Electrical and Electronic Engineers (EIA/IEEE) standards for serial line communications interfaces. The RS-232 standard uses low voltage (5 volts or less) signals over 9 conductor or 25 conductor cables, with a maximum transmission distance of 100 ft. Both RS-422 and RS-485 use a twisted-pair wire (i.e. 2 wires) for each signal. They both use the same differential drive with identical voltage swings: 0 to +5V and support transmission distances up to 4000 feet. The main difference between RS-422 and RS-485 is that while RS-422 is strictly for point-to-point communications (and the driver is always enabled), RS-485 can be used for multi-drop systems (and the driver has a tri-state capability).**
IEEE 802.11	**802.11 (also known as Wi-Fi) refers to a family of specifications developed by the IEEE for wireless LAN technology. 802.11 specifies an over the air interface between a wireless client and a base station or between two wireless clients. The IEEE accepted the specification in 1997.** **There are several specifications in the 802.11 family:** • **802.11 -- applies to wireless LANs and provides 1 or 2 Mbps transmission in the 2.4 GHz band using either Frequency Hopping Spread Spectrum (FHSS) or Direct Sequence Spread Spectrum (DSSS).** • **802.11a -- an extension to 802.11 that applies to wireless LANs and provides up to 54 Mbps in the 5 GHz band. 802.11a uses an orthogonal frequency division multiplexing encoding scheme rather than FHSS or DSSS.** • **802.11b (also referred to as *802.11 High Rate* or *Wi-Fi*) -- an extension to 802.11 that applies to wireless LANS and provides 11 Mbps transmission (with a fallback to 5.5, 2, and 1 Mbps) in the 2.4 GHz band. 802.11b uses only DSSS. 802.11b was a 1999 ratification to the original 802.11 standard, allowing wireless functionality comparable to Ethernet.** **802.11g -- applies to wireless LANs and provides 20+ Mbps in the 2.4 GHz band.**
IEEE 802.16e	**802.16 (also known as WiMAX) refers to a family of specification for metro-access wireless Ethernet for fixed and mobile applications. WiMAX will be certified in the 2.5-3.5 GHz spectrum for licensed deployments, and in the 5 GHz spectrum for unlicensed deployments. The specification defines data rates up to 75 Mbps when 20 MHz channels are used. A typical 7 km (4 mile radius) cell with 10 MHz channels can usually support a 22 Mbps data rate.**
IEEE 802.3ae	**IEEE 802.3ae defines a version of Ethernet with a nominal data rate of 10 Gbps, ten times faster than gigabit Ethernet. The new 10-gigabit Ethernet standard encompasses seven different media types for LAN, Metropolitan Area Network (MAN) and WAN. It is currently specified by a supplementary standard, IEEE 802.3ae, and will be incorporated into a future revision of the IEEE 802.3 standard.** **10GBASE-SR ("short range") -- Designed to support short distances over deployed multimode fiber cabling, it has a range between 26 m and 82 m depending on the cable type. It also supports 300 m operation over a new 2000 MHz·km multimode fiber.** **10GBASE-CX4 -- Copper interface using Infiniband cables for short reach applications (such as aggregation switch to router). This is currently the lowest cost per port interface at the expense of transmission range.** **10GBASE-LX4 -- Uses wavelength division multiplexing to support ranges between 240 m and 300 m over deployed multimode cabling. Also supports 10 km over single mode fiber.** **10GBASE-LR and 10GBASE-ER ("long range" and "extended range") -- These standards support 10 km and 40 km respectively over single mode fiber. Recently several manufacturers have introduced 80 km range ER pluggable interfaces.** **10GBASE-SW, 10GBASE-LW and 10GBASE-EW -- These varieties use the WAN PHY, designed to interoperate with OC-192/STM-64 SONET/SDH equipment. They correspond at the physical layer to 10GBASE-SR, 10GBASE-LR and 10GBASE-ER respectively, and hence use the same types of fiber and support the same distances. (There is no WAN PHY standard corresponding to 10GBASE-LX4.)** **Unlike earlier Ethernet systems, 10-gigabit Ethernet is based entirely on the use of optical fiber connections. However, the IEEE is developing a standard for 10-gigabit Ethernet over twisted pairs (10GBaseT), using Cat-6 or Cat-7 cable and planned for approval in 2006. Additionally, this developing standard is moving away from local area network design, with broadcasting to all nodes, towards a system which includes some elements of wide area routing. It is claimed that this system has high compatibility with earlier Ethernet and IEEE 802 networks.**
JPEG	**Joint Photographic Expert Groups. Compression technique that causes some detail to be lost during compression.**

Standard	Description
MJPEG	**Motion JPEG. A moving image which is made by storing each frame of a moving picture sequence in JPEG compression, then decompressing and displaying each frame at rapid speed to show the moving picture.**
MPEG	**Moving Picture Experts Group. Family of digital video compression standards and file formats. There are three major standards: MPEG-1, MPEG-2 and MPEG-4**
NMEA-0183	**National Marine Electronics Association standard for electrical interfaces and data protocol for communications between marine instrumentation. The standard includes the RMC message definition, which is the Recommended Minimum Content message for GPS/Transit data. The standard is based on an EIA RS-422 electrical interface.**
NTCIP 1403	**TCIP – Passenger Information (PI) Business Area Standard**
NTCIP 1404	**TCIP - Standard on Scheduling/Runcutting (SCH) Objects**
NTCIP 1405	**TCIP - Standard on Spatial Representation (SP) Objects**
NTCIP 2202	**NTCIP Transport Profile for Internet (TCP/IP and UDP/IP)**
NTCIP 2303	**NTCIP Application Profile for File Transfer Protocol (FTP)**
NTCIP 2306	**NTCIP XML in ITS Center-to-Center Communications**
SAE J1708	**Standard for serial data communications between microcomputer systems in heavy-duty vehicle applications**
SAE J2266	**Location referencing Message Specification (LRMS)**
SAE J2353	**Data Dictionary for Advanced Traveler Information System (ATIS)**
SAE J2354	**Message Set for Advanced Traveler Information System (ATIS)**
SAE J2374	**National Location Referencing Information Report**
SAE J2529	**Rules for Standardizing Street Names and Route IDs**
SAE J2540	**Messages for Handling Strings and Look-Up Tables in ATIS Standards**
TMDD	**Traffic Management Data Dictionary (see ITE TM 1.03)**
XML	**eXtensible Markup Language – Version 1.0 of the specification is available at: http://www.w3.org/tr/2000/REC-xml-20001006.html**
XSLT	**eXtensible Stylesheet Language Transformations – Version 1.0 of the XSLT specification is available at: http://www.w3.org/tr/1999/REC-exlt-19991116.html**

8 NATIONAL ITS ARCHITECTURE VIEWPOINT

This viewpoint provides the U.S. Department of Transportation, participating agencies, and other interested parties with an understanding of how the proposed system fits into the National ITS Architecture. This includes the system's relationship to the standard market packages and to the National ITS Physical and Logical Architectures.

FTA has adopted the FHWA Title 23 Code of Federal Regulations (CFR) §940 (ITS Final Rule) as referenced in Title 49 CFR §600 (FTA Regulations). This is commonly referred to as the final rule on conformance of ITS systems and projects to the National ITS Architecture and associated standards. This architecture viewpoint allocates the components of the StarTran AVL system according to the structure and viewpoint of the National ITS Architecture.

System functions in the National ITS Architecture are described in three representations: market packages, a physical architecture (in terms of subsystems, terminators, and equipment packages), and a logical architecture (in terms of processes and the data flows between them). A complete description of these representations and their associated object classes can be found in the referenced National ITS Architecture documentation. The description of the National ITS Architecture herein is limited to those aspects of the architecture that are specifically related to the proposed system, including some allowance for those capabilities identified as optional functions.

8.1 Physical Architecture

In the language of the National ITS Architecture, the *Physical Architecture* is comprised of transportation, communications, and institutional layers. The transportation layer includes the various transportation-related processing centers, distributed roadside equipment, vehicle equipment, and other equipment used by travelers to access ITS services. The communication layer provides for the transfer of information between the transportation layer elements. The institutional layer introduces the policies, funding incentives, working arrangements, and jurisdictional structure that support the technical layers of the Physical Architecture.

Within the physical architecture, *subsystems* are used to describe collections of specific processing functions related to real-world transportation systems. *Terminators* are real-world users of and objects associated with the transportation systems; in the physical architecture, terminators interact with the subsystems, but are outside the scope of the transportation system itself. Terminators can be sources of information or consumers of information.

The Transportation and Communication Layers together are the *Architecture Framework* that coordinates overall system operation by defining what each major transportation system element does and how the system elements collectively interact to provide user services. Figure 16 shows a high-level view of the Architecture Framework. The un-shaded areas of the figure indicate the elements corresponding to the StarTran AVL system.

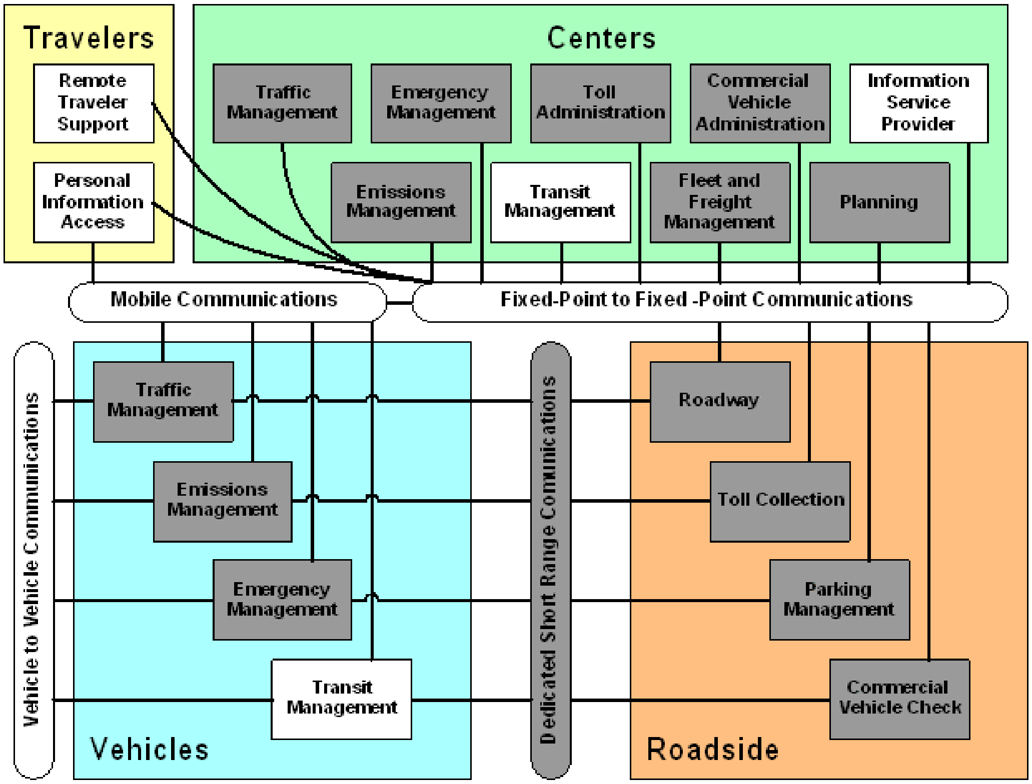

Figure 16 - Architecture Framework

8.2 *Market Packages*

Market packages represent functional groupings within the Physical Architecture that correspond to specific services. Market packages are collections of functions (the “package”) that can be used together to meet a related group of operational needs (the “market”). A market package does not necessarily correspond to a specific product or system. Version 5.0 of the National ITS Architecture describes eighty-five (85) market packages to represent the breadth of capabilities in the overall architecture. Table 2 illustrates the distribution of transit system components in the context of these market packages. This list is limited to those market packages that would likely be the responsibility of StarTran, specifically transit-related market packages, or provided functionality required to connect to future systems.

Each of these listed market packages will be described further after the Table 1. Other market packages, such as those required to implement a traffic signal priority system or a road weather information system, are left to other design documents.

Table 2 - Market Packages Relating to Transit Systems

Market Package	Market Package Name
APTS1	Transit Vehicle Tracking
APTS2	Transit Fixed-Route Operations
APTS3	Demand Response Transit Operations
APTS4	Transit Passenger and Fare Management
APTS5	Transit Security
APTS6	Transit Maintenance

APTS7	Multi-modal Coordination
APTS8	Transit Traveler Information

8.2.1 APTS1 – Transit Vehicle Tracking

This market package monitors current transit vehicle location using an AVL system. The location data may be used to determine real time schedule adherence and update StarTran's schedule in real-time. Vehicle position may be determined either by the vehicle (e.g., through GPS) and relayed to the infrastructure or may be determined directly by the communications infrastructure. A two-way wireless communication link with the Transit Management Subsystem is used for relaying vehicle position and control measures. Fixed route transit systems can also employ beacons along the route to enable position determination and facilitate communications with each vehicle at fixed intervals. The Transit Management Subsystem processes this information, updates the StarTran schedule, and makes real-time schedule information available to the Information Service Provider (ISP), which may be StarTran or another entity.

8.2.2 APTS2 – Transit Fixed-Route Operations

This market package performs vehicle routing and scheduling, as well as automatic operator assignment and system monitoring for fixed-route and flexible-route transit services. This service determines current schedule performance using AVL data and provides information displays at the Transit Management Subsystem. Static and real time transit data is exchanged with an ISP where it may be integrated with information from other transportation modes.

8.2.3 APTS3 – Demand Response Transit Operations

This market package performs vehicle routing and scheduling as well as automatic operator assignment and monitoring for demand responsive transit services. In addition, this market package performs similar functions to support dynamic features of flexible-route transit services, creating some overlap with APTS2. The APTS3 package monitors the current status of the transit fleet and supports allocation of these fleet resources to service incoming requests for transit service while also considering traffic and road conditions. The Transit Management Subsystem provides the necessary data processing and information display to assist the StarTran dispatcher in making optimal use of the transit fleet. This service includes the capability for a traveler request for personalized transit services to be made through the ISP Subsystem. The ISP may either be operated by StarTran or be independently owned and operated by a separate service provider. In the first scenario, the traveler makes a direct request to StarTran for paratransit service. In the second scenario, a third party service provider determines that the StarTran paratransit service is a viable means of satisfying a traveler request and makes a reservation for the traveler.

8.2.4 APTS4 – Transit Passenger and Fare Management

This market package manages passenger loading and fare payments on-board transit vehicles using electronic means. It would allow StarTran users to use a traveler card or other electronic payment device. Sensors mounted on the vehicle permit the bus operator and StarTran's central operations to determine vehicle loads, and readers located within the infrastructure or on-board the transit vehicle allow electronic fare payment. Data is processed, stored, and displayed on the transit vehicle and communicated as needed to the Transit Management Subsystem.

8.2.5 APTS5 – Transit Security

This market package provides for the physical security of transit passengers and transit vehicle operators. On-board equipment is deployed to perform surveillance and sensor monitoring in order to warn of potentially hazardous situations. The surveillance equipment includes video (e.g., CCTV cameras), audio systems, and/or event recorder systems. Additional sensor equipment may include threat sensors (e.g., chemical agent, toxic industrial chemical, biological, explosives, and radiological sensors) and object detection sensors (e.g., metal detectors). Transit user or transit vehicle operator activated alarms are provided on-board. Public areas (e.g., transit stops, park and ride lots, stations) can also be monitored with similar surveillance and sensor equipment and provided with transit user activated alarms. In addition, this market package provides surveillance and sensor monitoring of non-public areas of transit facilities (e.g., transit yards) and transit infrastructure such as bridges, rail crossings, etc. The public and non-public surveillance equipment includes video and/or audio systems. The public and non-public sensor equipment can include threat sensors and object detection sensors as described above as well as intrusion or motion detection sensors and infrastructure integrity monitoring (e.g., bridge structural integrity monitoring).

The non-public area surveillance and sensor information can be transmitted directly to the Emergency Management Subsystem, as can transit user-activated alarms in public secure areas. On-board alarms, activated by transit users or transit vehicle operators can be transmitted to both the Emergency Management Subsystem and the Transit Management Subsystem, indicating two possible approaches to implementing this market package. In addition, the market package supports remote transit vehicle disabling by the Transit Management Subsystem and transit vehicle operator authentication.

8.2.6 APTS6 – Transit Maintenance

This market package supports automatic transit maintenance scheduling and monitoring. On-board condition sensors monitor system status and transmit critical status information to the Transit Management Subsystem. Hardware and software in the Transit Management Subsystem processes this data and schedules preventative and corrective maintenance in conjunction with the StarTran fleet maintenance personnel.

8.2.7 APTS7 – Multi-modal Coordination

This market package establishes two-way communications between multiple transit and traffic agencies to improve service coordination. This package provides the functionality required for any future traffic signal priority system. Coordination between traffic and transit management is intended to improve on-time performance of the transit system to the extent that this can be accommodated without degrading overall performance of the traffic network. More limited local coordination between the transit vehicle and the individual intersection for signal priority is also supported by this package.

8.2.8 APTS8 – Transit Traveler Information

This market package provides StarTran users at transit stops and on-board transit vehicles with ready access to transit information. The information services include transit stop announcements, imminent arrival signs, and real-time transit schedule displays that are of general interest to transit users. Systems that provide custom transit trip itineraries and other tailored transit information services are also represented by this market package.

8.3 Logical Architecture

The Logical Architecture models the flow of data and control through various functional groups included in the Physical Architecture and the Market Packages. Data Flow Diagrams (DFDs) are used to illustrate the flow of data between the functional elements that make up the architecture. Figure 17 shows the high-level Data Flow Diagram for the elements comprising the StarTran AVL system.

This diagram combines terminators and functional groupings, and shows only the highest level data flows.

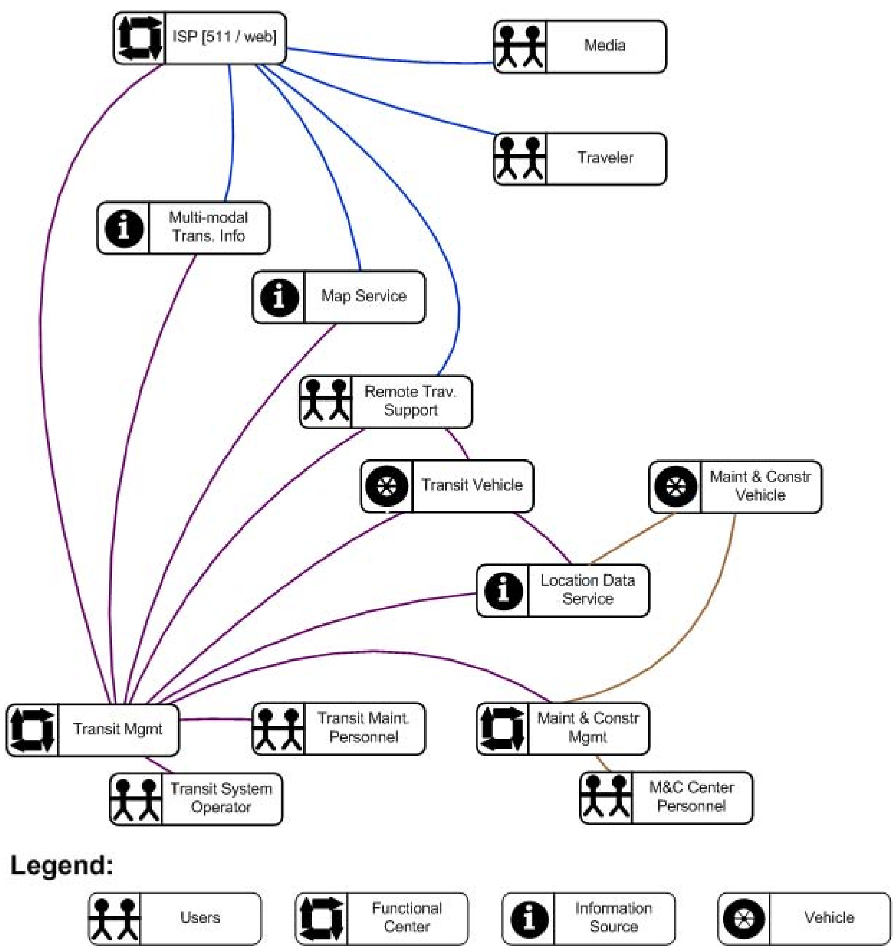

Figure 17 – High-Level Data Flow Diagram for the StarTran AVL System

9 REGIONAL ITS ARCHITECTURE VIEWPOINT

This viewpoint provides the participating agencies, regional architecture maintainers, and other interested parties with an understanding of how the proposed system fits into the Regional ITS Architectures. This includes the system's impact on the regional architectures and the system's relationship to the standard Market Packages and to the National ITS Physical and Logical Architectures. The regional architecture in this case is the Southeast Nebraska Regional ITS Architecture.

Figure 18 below shows the Project Interface Diagram for ***Project 13 – StarTran Automated Vehicle Location*** within the Southeast Nebraska Regional ITS Architecture. The figure also includes elements of ***Project 14 – StarTran Transit Information Improvements***, ***Project 24 – Multi-Jurisdictional Transit Coordination,*** and ***Project 29 – City of Lincoln Maintenance Vehicle Tracking***.

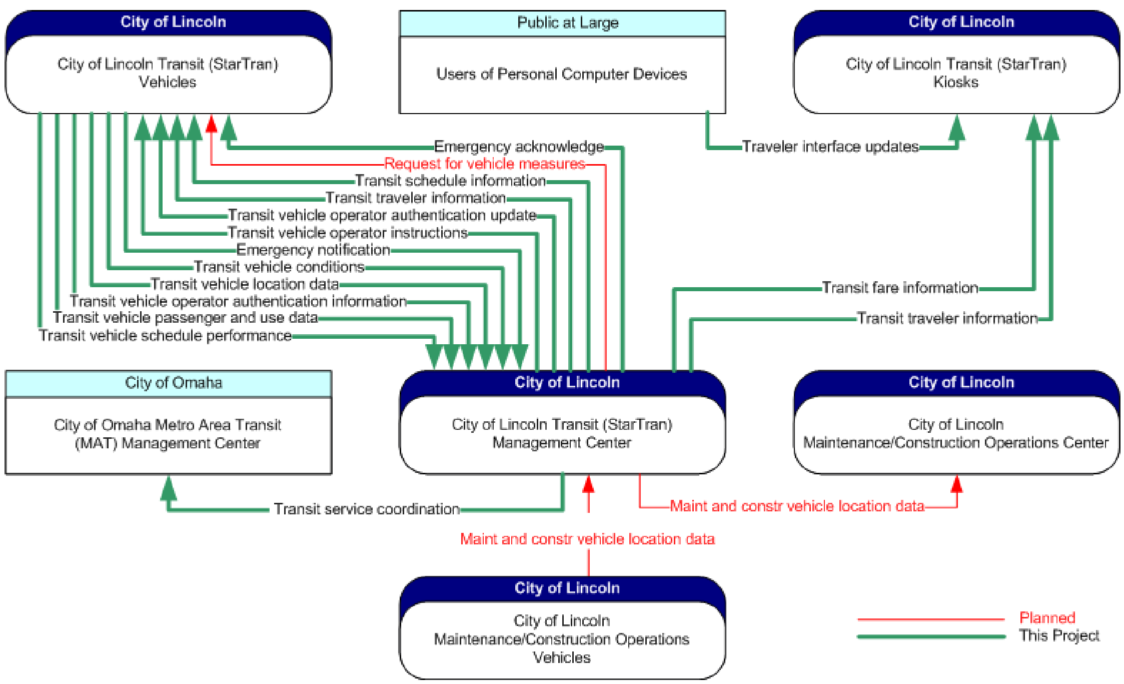

Figure 18 - AVL Project Interface Diagram

In the regional architecture, Project 13 – StarTran Automated Vehicle Location (AVL) is described as providing StarTran the ability to track transit vehicle locations. The location data could be used to determine schedule adherence and update the transit system's schedule in real-time for both fixed-route and paratransit.

For paratransit, it may also be used to determine a vehicle's location and whether it is in a good location for picking up an additional passenger. For fixed route, the tracking service may be used to measure schedule adherence and collect data to be used for planning.

The regional architecture also indicated that vehicle location may also be shared with other jurisdictions through ***Project 25 – Multi-Jurisdictional Transit Coordination*** and ***Project 36 – Local Transit Vehicle Tracking.***

9.1 Impact on Regional Architecture

The AVL project will implement a significant portion of the information flows and functionality that are currently listed as "Planned" in Project 13 of the regional architecture.

Preliminary planning for this project suggests that the vehicle location infrastructure may be used to support other transit, city, and state agencies. If this is accomplished, the Project Interface Diagrams for projects such as ***Project 29 – City of Lincoln Maintenance Vehicle Tracking*** would need to be modified to show the vehicle location information going to the StarTran Dispatch Center, and from there to the agency's dispatch center (see Figure 18 and the data flows for the City of Lincoln maintenance vehicles.)

Current planning for this AVL project indicates that as an option, and funding permitting, portions of ***Project 14 – StarTran Transit Information Improvements*** will also be implemented. This option will make additional schedule information available through the StarTran website and would publish the schedule information in a standard XML format that would eventually allow a 511 system to publish the schedule and fare information for StarTran.

StarTran has indicated that the vehicle condition monitoring data flows and functionality will be deployed at a later time. The data flow for transit vehicle passenger and use data and the associated functionality will be deployed at a later date in ***Project 15 – StarTran Transit Smart Card***.

9.2 Physical Architecture

This project will implement the Transit Management functions in the transit vehicles and at the StarTran dispatch center (see Figure 16), add remote traveler support in the form of visual and audio annunciators in the buses, and enhance the Personal Information Access capabilities of the existing StarTran website. The entire communications infrastructure required for this project is currently in place.

9.3 Market Packages

The AVL project will implement most of the functionality described in section 8.2 of this architecture for the market package listed in Table 3.

Table 3 - Market Packages relating to the StarTran AVL system

Market Package	Market Package Name
APTS1	Transit Vehicle Tracking
APTS2	Transit Fixed-Route Operations
APTS3	Demand Response Transit Operations
APTS5	Transit Security
APTS7	Multi-modal Coordination
APTS8	Transit Traveler Information

The functionality relating to APTS4 (Transit Passenger and Fare Management) and APTS6 (Transit Maintenance) have been deferred to later projects.

9.4 Logical Architecture

Figure 18 shows the resulting information flows for the regional architecture as it relates to this project.

APPENDIX A - DEFINITIONS, ACRONYMS, AND ABBREVIATIONS

The following table provides the definitions of all terms, acronyms, and abbreviations required to properly interpret this Concept of Operations.

Term	Definition
1xRTT	One channel Radio Transmission Technology
Acquirer	An organization that procures a system, software product, or software service from a supplier. (The acquirer could be a buyer, customer, owner, user, or purchaser.)
ADA	Americans with Disabilities Act
ANSI	American National Standards Institute
APTS	Advanced Public Transportation System
Architect	The person, team, or organization responsible for systems architecture.
Architecting	The activities of defining, documenting, maintaining, improving, and certifying proper implementation of an architecture.
Architectural Description (AD)	A collection of products to document a project architecture.
Architecture	The fundamental organization of a system embodied in its components, their relationships to each other, and to the environment, and the principles guiding its design and evolution.
ATIS	Advanced Traveler Information System
AVL	Automated Vehicle Location
CAD	Computer Aided Dispatch or Computer Automated Drafting
CCTV	Closed-Circuit Television
CDPD	Cellular Digital Packet Data
CFR	Code of Federal Regulations
COTS	Commercial Off-the-Shelf
CVO	Commercial Vehicle Operations
DSSS	Direct Sequence Spread Spectrum
EDACS	Enhanced Digital Access Communication System
EDGE	Enhanced Data Rates for GSM Evolution
EIA	Electronic Industries Alliance
ER	Extended Range
ESRI	Environmental Systems Research Institute, Inc. – A manufacturer of GIS application software.
FHSS	Frequency Hopping Spread Spectrum

FHWA	Federal Highway Administration
FMS	Freeway Management System
FTA	Federal Transit Administration
FTP	File Transfer Protocol
FY	Fiscal Year
Gbps	Giga bits per second (1,000,000,000 bits per second)
GHz	Giga Hertz (1,000,000,000 cycles per second)
GPRS	General Packet Radio Service
GPS	Global Positioning System
GSM	Global System for Mobile Communications
HTML	Hyper Text Markup Language
HTTP	Hyper Text Terminal Protocol
HTTPS	Secure Hyper Text Terminal Protocol
IEEE	Institute of Electrical and Electronics Engineers
IETF	Internet Engineering Task Force
IM	Incident Management
ISBN	International Standard Book Number
ISP	Information Service Provider
IT	Information Technology
ITE	Institute of Transportation Engineers
ITS	Intelligent Transportation System
JPEG	Joint Photographic Expert Groups. Compression technique that causes some detail to be lost during compression.
Kbps	Kilo bits per second (1000 bits per second)
Km	Kilometer (1000 meters)
LAN	Local Area Network
Life cycle model	A framework containing the processes, activities, and tasks involved in the development, operation, and maintenance of a software product, which spans the life of the system from the definition of its requirements to the termination of its use.
LRMS	Location Referencing Message Specifications
LRTP	Long Range Transportation Plan
m	Meter
MAN	Metropolitan Area Network
MAT	Metro Area Transit – Transit provider in Omaha, Nebraska
Mbps	Mega bits per second (1,000,000 bits per second)
MDT	Mobile Data Terminal

MHz	Mega Hertz (1,000,000 cycles per second)
MJPEG	Motion JPEG. A moving image which is made by storing each frame of a moving picture sequence in JPEG compression, then decompressing and displaying each frame at rapid speed to show the moving picture.
MPEG	Moving Picture Experts Group. Family of digital video compression standards and file formats. There are three major standards: MPEG-1, MPEG-2 and MPEG-4
MPO	Metropolitan Planning Organization
NDOR	Nebraska Department of Roads
NEMA	Nebraska Emergency Management Agency
NMEA	National Marine Electronics Association
NPSPAC	National Public Safety Planning Advisory Committee
NSP	Nebraska State Patrol
NTCIP	National Transportation Communication for ITS Protocol
PI	Passenger Information
POTS	Plain Old Telephone System
RMC	Recommended Minimum Content
RWIS	Road Weather Information Systems
SAE	Society of Automotive Engineers
Sunset	A term to describe a plan for long term phase-out of a technology
System	A collection of components organized to accomplish a specific function of set of functions.
TCP/IP	Transmission Control Protocol/ Internet Protocol
TIA	Telecommunications Industry Association
TIP	Transportation Improvement Plan
UNL	University of Nebraska, Lincoln
VHF	Very High Frequency
View	A representation of a whole system from the perspective of a related set of concerns.
Viewpoint	A specification of the conventions for constructing and using a view. A pattern or template from which to develop individual views by establishing the purposes and audience for a view and the techniques for its creation and analysis.
VoIP	Voice over Internet Protocol or Voice over IP. Sending voice information in digital (packets) rather than in the traditional circuit-committed protocols of the public switched telephone network.
WAN	Wide Area Network
Waypoint	A waypoint is a specified geographical location, spot or destination defined by longitude and latitude used for navigational purposes. It

	is used in the definition of routes and terminal segments.
Wi-Fi	Wireless fidelity. Used generically when referring to any type of 802.11 network.
WiMAX	Wireless Interoperability for Microwave Access. Used generically when referring to any type of 802.16 network.
XML	eXtensible Markup Language
XSLT	eXtensible Stylesheet Language Transformations